Senior Seminar on The Wealth and Well-Being of Nations:

Each year, seniors in the department of economics participate in a semester-long course that is built around the ideas and influence of that year's Upton Scholar. By the time the Upton Scholar arrives in October, students will have read several of his or her books and research by other scholars that has been influenced by these writings. This advanced preparation provides students the rare opportunity to engage with a leading intellectual figure on a substantive and scholarly level.

Endowed Student Internship Awards:

A portion of the Miller Upton Memorial Endowments supports exceptional students pursuing high-impact internship experiences. Students are encouraged to pursue internships with for-profit firms and non-profit research organizations dedicated to advancing the wealth and well-being of nations.

Charles G. Koch Student Research Colloquium and Speaker Series:

With generous support from the Charles G. Koch Charitable Foundation, the department has initiated a research colloquium that gives students the opportunity to read and discuss seminal articles aimed at deepening their understanding of the market process. Students also develop original analysis that applies economic ideas to novel contexts. Colloquium participants receive close mentoring as they craft an article with the eventual goal of publication in a newspaper, magazine, or academic journal. The themes of the research colloquium and annual forum are supported with a speaker series featuring the next generation of scholars working on questions central to our understanding of the nature and causes of wealth and well-being.

Annual Proceedings of The Wealth and Well-Being of Nations:

The keynote address presented by the Upton Scholar is an important contribution to the public discourse on the nature and causes of wealth and well-being. Further, the annual forum includes presentations by noted scholars who expand upon or challenge the work of the Upton Scholar. These presentations are assembled in the *Annual Proceedings of the Wealth and Well-Being of Nations*, which serves as an important intellectual resource for students, alumni, and leaders within higher education.

The Annual Proceedings of the Wealth and Well-Being of Nations

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Contents

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Introduction

Warren Bruce Palmer[1]

It was my singular pleasure to organize and direct the 2014 Miller Upton Forum on "Economic Policy and the Challenges of Climate Change" featuring the 2014 Miller Upton Scholar Robert N. Stavins and eleven other speakers from academia, government and industry.

In turn, it is my privilege to introduce the seventh *Annual Proceedings of the Wealth and Well-being of Nations* composed of papers presented at the Forum.

With its signature Miller Upton Programs, the Department of Economics at Beloit College focuses the attention of its students, faculty, broader College community and alumni on the core issues of what promotes and what impedes the wealth and well-being of nations.

The centerpiece of this suite of programs is the annual Wealth and Well-being of Nations: A Forum in Honor of Miller Upton. Held each fall, the Miller Upton Forum features one of the world's most influential thinkers on the ideas and institutions necessary for advancing the wealth and well-being of the nations and peoples of the world. Each year's Miller Upton Scholar is joined on campus by a group of other thinkers and practitioners who engage our students, faculty and broader community in enlightening classroom discussions, panel discussions, and one-on-one conversations.

The Miller Upton Programs and the Miller Upton Forum are named in honor of Miller Upton, the sixth President of Beloit College, and are inspired by Miller's unflagging dedication to the ideals of a liberal society: political freedom, the rule of law, and peace and prosperity through the voluntary exchange of goods and ideas.

Inspired by Miller Upton's example, Beloit College Professors Jeff Adams and Emily Chamlee-Wright designed the Miller Upton Programs to intellectually challenge majors in the Department of Economics. William Fitzgerald'86 and Bob Virgil'56 chaired an endowment campaign to fund the Miller Upton

1 Warren Bruce Palmer is the Elbert H. Neese, Jr. Professor of Economics.

Programs. Donors responded enthusiastically and gave generously, providing the resources to sustain the Miller Upton Programs at a high level of achievement and to bring the world's most influential thinkers on the wealth and well-being of nations to the Beloit College campus.

Our focus on the wealth and well-being of nations consciously evokes the intellectual enterprise launched by Adam Smith in his seminal treatise on *The Wealth of Nations*. Amazed at the rapid growth in output spawned by the early stages of the industrial revolution, Smith remarked early in his work on the rapid growth of labor productivity in a pin factory, noting the crucial interactions between the division of labor, the extent of markets and the systematic development of productive processes.

The growth in productivity Smith observed has continued unabated since his day. Modern economic growth -- manifested as rapid innovation in products and processes and represented by the growth in real per capita GDP over successive generations -- results from the systematic development of new scientific, technical knowledge and its entrepreneurial application to the continual development and transformation of agriculture, industry, commerce, transportation, and information.

Previous Upton Forums studied the institutional foundations that support the growth in humanity's productive powers. In the seventh Upton Forum, we turned our attention to one of the greatest long-run threats to continued growth in the wealth and well-being of nations: anthropogenic climate change.

The modern economy consists of electro-mechanical production systems powered by inanimate energy, especially electric power, and linked together by mass transportation systems, powered by refined fossil fuels and electric power, able to move goods and information rapidly throughout the economy at low cost. Through the focused application of inanimate energy, these electro-mechanical production and transportation systems greatly magnify human effort, and their continual development is caused by and results in the continual invention and refinement of new products and production process.

Modern energy systems allow us to modify the environment so that we can enjoy longer, fuller, richer, healthier lives. So far, the net impact of modern energy systems has been to improve the environment within which we live, although all along these energy systems have produced negative environmental externalities that have been inadequately considered in market and non-market transactions. Moreover, it has become clear in recent decades that fossil fuels so effectively harnessed to power modern economic growth literally carry within them one of the greatest long-run threats to sustainable prosperity: rising levels of atmospheric carbon dioxide. Higher atmospheric concentrations of carbon dioxide and other anthropogenic greenhouse gases cause a net radiative forcing, increasing average global temperatures and adversely altering climates over time. Despite the political rhetoric that seeks to create scientific controversy where none exists, the same science that undergirds the creation of humanity's wealth-creating inventions is the same science that describes how increasing the trace amounts of carbon dioxide and other anthropogenic greenhouse gases in the atmosphere will increase the absorption of infrared radiation by the atmosphere and its re-radiation back toward earth, raising global temperatures and altering climates. Great uncertainty exists in the nature and extent of these climate changes, but the uncertainty is almost entirely over the timing and severity of climate changes that could be much more harmful to humanity's wealth and well-being than even those generally predicted. (Weitzman 2014, Wagner and Weitzman 2015)

Robert N. Stavins, Seventh Miller Upton Scholar

When we decided to focus the seventh Miller Upton Forum on economic policy and the challenges of climate change, our thoughts naturally turned to Robert N. Stavins, one of the world's leading thinkers on effective international climate change policy and agreements.

He is the Albert Pratt Professor of Business and Government, Director of the Harvard Environmental Economics Program, Chairman of the Environment and Natural Resources Faculty Group at the John F. Kennedy School of Government, Harvard University, and Director of Graduate Studies for the Doctoral Program in Public Policy and the Doctoral Program in Political Economy and Government, and Co-Chair of the Harvard Business School-Kennedy School Joint Degree Programs, and Director of the Harvard Project on Climate Agreements. He is a University Fellow of Resources for the Future, a Research Associate of the National Bureau of Economic Research, Co-Editor of the *Review of Environmental Economics and Policy*, and a Member of: the Board of Academic Advisors of the Regulatory Markets Center, the Board of Directors of the Robert and Renée Belfer Center for Science and International Affairs, the Editorial Boards of *Resource and Energy Economics*, *Climate Change Economics*, *Environmental Economics and Policy Studies, Environmental Economics Abstracts*, *Environmental Law* *and Policy Abstracts*, *B.E. Journals of Economic Analysis & Policy*, and *Economic Issues*. He is also a Vice-President of the American Association of Wine Economists, an editor of the *Journal of Wine Economics*, and the Chair of the Expert Advisory Board of the Harvard Alumni Alliance for the Environment.

As the above list of official roles taken from Professor Stavins' website shows, he is a very busy scholar, educator and policy consultant. We most appreciated his accepting the invitation to serve as the seventh Upton Scholar. Although this was his first visit to Beloit College, the early stages of his educational and career path felt familiar to Beloiters, rooted as it was in liberal education and echoing key elements of the Beloit College Mission Statement:

"Beloit College engages the intelligence, imagination, and curiosity of its students, empowering them to lead fulfilling lives marked by high achievement, personal responsibility, and public contribution in a diverse society. Our emphasis on international and interdisciplinary perspectives, the integration of knowledge with experience, and close collaboration among peers, professors, and staff equips our students to approach the complex problems of the world ethically and thoughtfully."

Robert Stavins career embodies what the mission statement extolls. (Stavins 2012) Following the completion of his undergraduate philosophy major at Northwestern University, another good, Midwestern institution of higher education, he spent the next four years as a Peace Corps Volunteer in Sierra Leone, helping improve rice cultivation. The experience transformed and refocused his ambitions, leading him to complete an M.S. degree in agricultural economics at Cornell University, followed by an extended stint with the Environmental Defense Fund working on water policy in California where he experienced "for the first time the use of economic analysis in pursuit of better environmental policy." (He has been engaged in this pursuit ever since, and today is widely known as one of the world's best and most effective environmental policy experts.) His recognition of the need for effective environmental policy grounded in economic theory then made Harvard University the next logical stop in his educational and career path. Undeterred by the absence of an environmental economics program in Harvard's Economics Department, Stavins created a self-designed Ph.D. field in environmental and resource economics. Following graduation in 1988, attracted by "the possibility of combining an academic career with extensive involvement in the development of public policy", Stavins joined the Kennedy School where he has been ever since, becoming the Albert Pratt Professor of Business and Government in 1998 and founding the Harvard Environmental Economics Program in 2000.

Professor Stavins has been a key figure in transforming environmental economic theory into effective public policy, starting with his direction of Project 88, a bipartisan program on environmental policy that helped lead to the highly effective, market-based Acid Rain Program enacted in the 1990 Clean Air Act. He has been deeply involved in the work of the Intergovernmental Panel on Climate Change (IPCC) recently serving as Co-Coordinating Lead Author of Chapter 13, "International Cooperation: Agreements and Instruments," of Working Group III (Mitigation) of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change. He is the founder and director of the Harvard Project on Climate Agreements, and has actively contributed to the work of the United Nations Framework Convention on Climate Change (UNFCCC).

Professor Stavins spent four stimulating days at Beloit College and was most generous with his time, energy, and knowledge. He spoke to nine Beloit College classes, participated in three panel discussions, attended four dinners and delivered The June and Edgar Martin Memorial Lecture, the keynote address of the Miller Upton Forum.

Economics and Climate Change Policy

In his keynote address, "What Can an Economist Possibly Have to Say about Climate Change?", Prof Stavins answered his own question, explaining how "an economic perspective" is "essential for a full understanding of environmental problems" and for designing "effective, economically sensible, and politically pragmatic" public policies. Nowhere is this more true than for designing cost-effective, politically feasible policies to address the challenges of global climate change. As Prof. Stavins notes, "Environmental problems are the unintended side effects of market activity." Producers and consumers engage in desirable production and consumption without having to consider certain harmful, unintended side effects that incomplete property rights render external to their decision-making. In his paper, Prof. Stavins reviews the case for national and international carbon pricing, calling greenhouse gas reduction a classic free rider problem: the costs to any economic agent of reducing greenhouse gas emissions exceed the benefits because the benefits are global while the costs are local. Only carbon pricing via cap-and-trade or carbon taxes can inject the costs and benefits of greenhouse gas reduction into individual decisions. Stavins' paper discusses multiple intersections between the economics and politics of greenhouse gas reduction, moving from domestic to international policy. His paper concludes by observing that past advances in environmental legislation have often been propelled by highly publicized environmental disasters. If domestic and international action on climate change requires "an obvious, sudden and perhaps cataclysmic event – such as loss of the Antarctic ice sheet leading to a dramatic sea-level rise", then such action will be too little, too late. Instead, Stavins concludes that "inspired leadership at the highest level" is needed to move climate change policy forward.

Four authors, Sheila Olmstead, Gernot Wagner, Yoram Bauman and Lynne Kiesling, presented papers at the panel discussion "The Ideas and Influence of Robert N. Stavins" on Friday, November 5, 2014. Robert Stavins has been at the forefront of applying market-based policy instruments to crafting effective, real-world environmental policy, and all of the panelists celebrated his achievements and built upon them in their papers, each of which addressed market-based environmental policy.

In "Markets and the Environment: Progress and Future Challenges," Sheila Olmstead summarizes the principles of market-based, economically-effective environmental policy, connecting the economic theory with policy implementation in a wide-range of environmental applications, noting the key role Robert Stavins played in translating theoretical principles into real-world policies. She provides a succinct review of market–based policy instruments for achieving cost-effective pollution reduction. Olmstead observes that such policy instruments have been less commonly used than command-and-control methods even though command-and-control methods cannot achieve cost-effective pollution reduction under conditions of heterogeneous abatement costs. Her paper summarizes the basic theory of tradeable pollution permits and pollution taxes, then summarizes noteworthy achievements in putting this theory into practice, such as the EPA's lead-trading policy in the 1980s, the SO_2 allowance system created by the 1990 Clean Air Act Amendments, individual tradeable quotas for fishing, water quality trading, and waste management policies. The paper then identifies key challenges to expanding the scope of market incentives in economic policy, observing that such instruments only account for "a tiny fraction of all U.S. environmental regulation."

In his article, "Linking Sound Economics with Global Politics", Gernot Wagner observes that the world's economies are in the "experimental phase" of "creating a global market for carbon". Heterogeneous abatement costs combined with carbon abatement being a global public good argues for such market-based incentives. Wagner focuses on the importance of linking national carbon markets because "it allows for more ambitious climate action at lower cost than separate domestic policies." Differential marginal abatement costs within and between nations makes a strong case for linking carbon abatement across nations, but significant political challenges exist in creating such linkages, such as the differential impact between nations that candidate carbon-reduction policies play in their domestic politics, the need to create robust regulatory frameworks assuring the quality of carbon abatement, and the design and implementation of national and international financial systems that facilitate the large scale financial flows resulting from effective linkage. Wagner's paper outlines these challenges, emphasizing the incremental, experimental development of mechanisms linking carbon abatement between nations. As the paper concludes, individual nations need to develop sound domestic infrastructure for domestic carbon markets in order to, in turn, create sound international infrastructure linking these domestic carbon markets. Effectively linking domestic carbon markets reduces the cost of achieving any given level of carbon abatement, which can then improve the political viability of carbon reduction policies.

In "Carbon Pricing: From Theory to Reality", Yoram Bauman describes and promotes efforts in Washington state to adopt a revenue neutral carbon tax, such as that implemented in British Columbia. Bauman, an environmental economist and standup comic, is a leader of Carbon Washington, the bipartisan group promoting Initiative 732 and collecting sufficient signatures to place the initiative before Washington voters. As described in Bauman's paper, Initiative 732 would institute a carbon tax of $25 per metric on fossil fuels used in Washington state, and would recycle the revenues raised to reduce the state sales tax by one percentage point, pay tax rebates to low-income working households, and eliminate the state business tax on manufacturers. His paper concludes with the Beloitsyburg Address, a tribute to Robert Stavins whose work Bauman cites in his paper.

Internalizing the cost of carbon emissions through market-based methods as described by the preceding papers increases entrepreneurs' incentives to develop less-carbon intensive technology, but such innovation requires a regulatory environment conducive to experimentation. In their paper, "Regulation, Innovation and Experimentation: The Case of Residential Rooftop Solar", Lynne Kiesling and Mark Silberg stress the importance of entrepreneurial experimentation in creating a low-carbon 21st century electricity system. They "identify four sets of experimentation factors that drive solar market growth", and explore a case study of the residential rooftop solar market. They conclude that developing a low-carbon electricity system requires regulatory policies conducive to producer and consumer experimentation, building on Kiesling's previous Upton Forum presentation (Kiesling 2012).

As discussed in the preceding papers, getting the prices right on anthropogenic greenhouse gas emissions and on low carbon energy sources are necessary components of a policy package to effectively move the global economy onto a path of lower anthropogenic greenhouse gas emissions and hopefully avoid the worst-case climate change scenarios caused by a warming planet. Entrepreneurial innovation in response to the changed prices is necessary to discover the least-cost path to a less carbon-intensive global economy. The remainder of the articles come from two entrepreneurially-themed panel discussions: "Energy Efficiency, Entrepreneurship, and Climate Change" on Tuesday, November 2, 2014, and "Renewable Energy, Entrepreneurship, and Climate Change on Thursday, November 4.

Mark Hanson, Director of Sustainable Services at Hoffman Planning, Design & Construction, Inc., Appleton, WI, makes the case that energy efficient buildings make sense now, even in the absence of pricing carbon into the economy. His firm has discovered that they can deliver state-of-the-art energy efficient buildings at construction costs comparable to conventional construction. According to Hanson, their experience calls into question the application of payback analysis to the "green" vs "conventional" construction choice. According to Hanson, no tradeoff exists between green and conventional construction if the initial cost of green construction matches that of conventional construction, yet saves energy costs during operation. He then discusses green projects successfully completed by his firm at reduced construction and operation cost with no decrease in building amenities or function.

Environmental attorney John Clancy discusses in his paper a financing arrangement applicable to renewable energy projects undertaken by non-profits in Wisconsin, such as Beloit College's proposed conversion of a decommissioned, river-front coal power plant into a new student union and recreation center. The proposed project, dubbed The Powerhouse, will be a green building, perhaps incorporating a unique isothermal skin heated and cooled geothermally. Clancy suggests that the College could add sufficient solar electricity on and near The Powerhouse to make the building a zero net energy building. Substantial tax incentives exist for installing solar PV, but these incentives do not apply if the

College builds and owns the solar system itself. Clancy describes an affiliate partnership arrangement with a taxable investor eligible for the Federal tax incentives that would make a large solar PV installation at Beloit College financially viable.

In his paper, entrepreneur, engineer and long-time environmentalist John Nelson outlines the opportunities that he sees in low carbon energy ventures, particularly small hydropower. At his firm, Global Infrastructure Asset Management, they believe that "the relationship between humanity and nature has to become more balanced," and that the market will reward entrepreneurs who find "the right financial-environmental balance". Nelson believes that "broad wealth creation" and "environmental stewardship" are "essential to the improvement of the human condition". His firm seeks projects that have some connection to two or more of the four key environmental endowments: habitat, energy, potable water, and atmosphere. Finding such projects and wisely investing in them can yield acceptable, long term financial and environmental returns.

In his paper, "Addressing Climate Change Should Boost the Economy", John Norquist, former mayor of Milwaukee and Past President of the Congress for the New Urbanism, discusses climate change and its connection to energy and buildings in the urban environment. He compares the climate change problem to ozone depletion, observing that solving the problem of chlorofluorocarbon emissions was much easier: fewer firms were affected and a straight-forward technological solution existed. Solving climate change is much harder because "the remedies are many", are opposed by the well-organized fossil fuel industry, and are perceived by the public to require much sacrifice. His paper makes the case that the degree of sacrifice is overstated, at least in relation to improving energy efficiency in cities. With the right government policies, cities could improve both their livability and their energy efficiency by pedestrian friendly, mixed used development.

Acknowledgements and Thanks

On behalf of the Department of Economics let me acknowledge and thank some of the many people who made the 2014 Miller Upton Forum the success it was. Jeff Adams and Jennifer Kodl originally proposed the climate change theme and the idea of my directing the 2014 Upton Forum. The talents and efforts of Jennifer Kodl, Program Coordinator to the Upton Programs and Managing Editor of this volume, have been crucial to the success of the Upton Forum since

its inception, and the success of the 2014 Upton Forum owes much to her management of an Upton Week that brought twelve speakers to campus and that was packed with three panel discussions, four dinners, two lunch meetings, and the keynote address by the Upton Scholar followed by a reception.

Science necessarily was a larger element in the 2014 Economics Senior Seminar than in past seminars, and I must thank all of the professors who made presentations in the Brownbag Series on the Science of Climate Change that met weekly prior to Upton week: Professors Theodore Gries, Yaffa Grossman, George Lisensky, Britt Scharringhausen, Brock Spencer, Paul Stanley, and Jonathon Warnock.

Let me also extend my gratitude to this year's members of the Economics Senior Seminar who eagerly embraced the opportunity to lift their economics education to a higher level, and demonstrated their success in doing so by intellectually engaging with the 2014 Upton Scholar, Robert Stavins, and all of the other scholars and experts who participated in the Upton Forum. As in years past, our students once again made the faculty of the Department of Economics proud to have been their professors.

Finally, continued thanks are due to the the many alumni, friends, and charitable foundations who have supported the Miller Upton Programs. Their initial support launched the Upton Programs on its successful trajectory, and their continued support has allowed the Department of Economics to invite successfully many of the world's top innovative scholars and practitioners who are committed to understanding and promoting the sources of the wealth and well-being of nations.

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What Can an Economist Possibly Have to Say about Climate Change?

Robert N. Stavins[1]

The June and Edgar Martin Memorial Lecture
2014 Upton Scholar, Beloit College
November 7, 2014

Some time ago, I boarded an airplane for a flight out of Boston's Logan Airport. As I sat down in my seat, it quickly became apparent that the person seated next to me wished to engage in a conversation. Perhaps you have noticed what I have, namely that there tend to be two kinds of people who fly – those who like to have conversations with perfect strangers, and the rest of us.

I am very much in that second category, and so as I sat down in my seat, I had work and a newspaper in front of me, anything to ward off an unwanted conversation. But the gentleman seated next to me persevered, and sought to start a conversation in what is typical fashion for Americans. He asked me, "What business are you in?" I did something foolish – I told the truth. I said, "I'm an environmental economist."

He looked at me, but did not say anything. I looked at him. This went on for what seemed to me to be a very long time. Here is this fellow who wanted to have a conversation, but he did not follow-up with another comment or question. Finally, it dawned upon me, and I understood why he was not saying anything further. I realized that he had concluded that he had just met a living, breathing

1 Robert Stavins is the Albert Pratt Professor of Business and Government at the Harvard Kennedy School, Research Associate of the National Bureau of Economic Research, and University Fellow of Resources for the Future. This essay is based upon the June and Edgar Martin Memorial Lecture, which I delivered on November 7, 2014, as the culmination of a week as the 2014 Upton Scholar at Beloit College. I wish to thank Professor Warren Palmer, my host for the week, President Scott Bierman, the faculty, and the students with whom I engaged. The intellectual engagement and the hospitality combined to make my visit one that I will not forget. Thanks are due to the entire Beloit College community.

oxymoron – an internal contradiction. After all, it is either the economy or the environment. So what could this phrase – environmental economics – even mean?

Is Environmental Economics an Internal Contradiction?

I would like to begin by explaining – and I hope demonstrating – that environmental economics is not oxymoronic. The reason I make this claim is, first, because the causes of environmental problems in a market economy (as exists in this country and in nearly all countries of the world) are economic. Environmental problems are the unintended side effects of market activity. When fundamentally desirable market activities are carried out, such as by producers manufacturing the goods that we as consumers wish to purchase and use, environmental pollutants are sometimes emitted in the process. Firms do not explicitly decide to emit those pollutants. Rather, those pollutant emissions are external to the decision-making frameworks of producers (and consumers), and for this reason, economists label these as externalities. So, the causes of environmental problems are economic.

The second reason I claim that environmental economics is not oxymoronic is that the consequences of environmental problems have important economic dimensions, as I will illustrate. So, if the causes of environmental problems are economic, and the consequences of environmental problems have important economic dimensions, then surely an economic perspective is important. Indeed, I will assert that it is essential for a full understanding of environmental problems, and therefore can be exceptionally helpful for the design of solutions – public policies – that are effective, economically sensible, and politically pragmatic. Such economic thinking is particularly important for the formulation of effective, sensible, and politically feasible climate policies (Stavins 2011a).

Thinking about Climate Change: Science, Economics, and Geopolitics

As is often the case in the realm of environmental economics, we must begin with the natural science, which takes us to the economics, and that takes us to the politics, in this case the geopolitics of global climate change.

Basic Science of Climate Change

The ever-growing concentrations of greenhouse gases in our atmosphere, caused by the burning of fossil fuels, appear likely to change our earth's climate in ways that many will come to regret. As reports from the Intergovernmental Panel on Climate Change (IPCC) make clear, decades of political inaction have increased the wisdom of intensive efforts over coming decades to avoid the worst consequences of global climate change (IPCC 2014c).

Scientists predict that severe consequences are likely to occur when global average temperatures increase by more than 2 degrees Centigrade (IPCC 2014a). Such a degree of warming would be caused by concentrations of greenhouse gases of about 450 parts per million (ppm) in CO_2-equivalent (CO_2eq) terms (IPCC 2013). But we are now on a path to more than double greenhouse concentrations, to about 1,000 ppm CO_2eq by the end of this century. This would result in average global temperature increases of 3 to 8 degrees Centigrade relative to pre-industrial levels.

Increased temperatures – which may be welcome in some places – are only part of the story. The most important consequences of climate change will be changes in rainfall patterns, disappearance of glaciers, decreased productivity of cereal crops, rise in sea levels, loss of islands and coastal wetlands, increased flooding, more frequent and intense storms, risk of species loss, and spread of infectious disease (IPCC 2014a).

From Science to Economics

The anticipated damages of climate change may be grave, but avoiding them by cutting greenhouse gas emissions will be neither cheap nor easy. Since the industrial revolution began, 300 years of economic growth have been fuelled by the combustion of fossil fuels – first coal, then petroleum, and most recently, natural gas. As a result, in the industrialized world, transport, energy and other infrastructure is highly dependent upon energy generated from fossil fuels. And the large emerging economies – China, India, Brazil, South Korea, Mexico, and South Africa – are rapidly putting in place new infrastructure that is likewise linked with the consumption of fossil fuels, and hence the emissions of more and more CO_2.

The IPCC found that the 450 ppm target can be achieved at an apparently low cost, namely a slowdown in consumption growth of only 0.06 percent a year from now through 2100 (IPCC 2014b). Those numbers are accurately reported, but potentially misleading. A small difference in the interest rate on my savings account can make a big difference in my bank balance after a couple of decades. Likewise, a very small difference in the average growth rate is very significant indeed when it occurs over a 100-year period, which is the case here. The widely-reported 0.06 percent difference in annual growth amounts to an estimated 5 percent loss of global consumption.

What is more, this cost estimate is based on a scenario with "optimal conditions". The assumption is that all countries immediately reduce their emissions to the necessary degree in a cost-effective manner, such as in reaction to a single global carbon price and with the help of various new technologies. Such optimal conditions are highly unlikely to be met. For example, if technologies for capturing the carbon emitted from burning fossil fuels (so-called carbon-capture-and-storage) are unavailable, then the costs of cutting emissions to the necessary levels more than double (IPCC 2014b).

So, from a purely economic perspective, the costs of achieving the 450 ppm target will be significant, but not necessarily unwarranted. A reasonable economic assessment of the target might be "very difficult, but not impossible." Things become more challenging when we move from economics to politics.

From Economics to Politics

Greenhouse gases mix in the atmosphere, and so the location of emissions has no effect on impacts. It does not matter whether greenhouse gases, such as carbon dioxide (CO_2), are emitted in Beloit, Wisconsin, Los Angeles, California, or Beijing, China. Their impacts are independent of the location of the emissions. Because of this, climate change is a global commons problem. Any jurisdiction taking action – a country, a province, or city – incurs the costs of its actions, but the direct climate benefits (averted climate change) are distributed globally. Therefore, for virtually any jurisdiction, the direct climate benefits it reaps from its actions will be less than the direct costs it incurs, despite the fact that the global benefits may be greater – possibly much greater – than the global costs (Stavins 2001).

This presents a classic free rider problem, which is why international, if not global, cooperation is essential. And it is also why the highest levels of effective governance need to be engaged, that is, national governments.

The Importance of Carbon Pricing

Most policy analysts favor a national carbon pricing policy, that is, a carbon tax or cap-and-trade system (Aldy and Stavins 2012b). Why? The first reason is that no other feasible approach can provide meaningful emissions reductions, for example, the U.S. target of an 83% cut in carbon dioxide emissions by 2050, relative to the 2005 level. Secondly, carbon pricing is the least costly approach in the short term, because abatement costs are highly heterogeneous. Carbon pricing has the effect of controlling all sources until their abatement costs on the margin are identical, which means that any aggregate amount of control is achieved at minimum cost. Thirdly, carbon pricing is the least costly approach in the long term, because it provides incentives for carbon-friendly technological change (Jaffe, Newell, and Stavins 2002).

Most policies have favored cap-and-trade over carbon taxes, largely for political reasons, which are related to experience (Schmalensee and Stavins 2013). In the 1980s, the U.S. Environmental Protection Agency (EPA) used cap-and-trade in its leaded gasoline phasedown to remove leaded gasoline from the market and replace it by unleaded gasoline during the period 1982 to 1987. The result was that leaded gasoline was removed from the market faster than had been anticipated and at an annual cost savings of approximately $250 million (Stavins 2003).

In the 1990s and during the first decade of the current century, emissions leading to acid rain were cut by half under the sulfur dioxide (SO_2) allowance trading program, enacted as part of the Clean Air Act amendments of 1990. Emissions were brought down faster than had been thought possible, and at a savings of approximately $1 billion per year, compared with what the cost would have been with any politically feasible alternative (Stavins 1998).

Turning next to cap-and-trade systems that have been used to address CO_2 and other greenhouse gas (GHG) emissions, the European Union Emissions Trading System (EU ETS), launched in 2008, is by far the world's largest cap-and-trade system, and the world's most important climate change policy (Ellerman and Buchner 2007). In the United States, the Regional Greenhouse Gas Initiative (RGGI) was launched in 2009 and is scheduled to continue at least through 2019. This cap-and-trade system focuses exclusively on the electricity generating sector.

Most recently, in California, a cap-and-trade system was launched in 2013, under the Global Warming Solutions Act of 2006. This policy is not only important in its magnitude, but also in its design, and for that reason merits more attention.

Lessons Learned from California's Cap-and-Trade System

California's Global Warming Solutions Act of 2006 is a broad and ambitious policy to cut greenhouse gas emissions in the State to their 1990 level by the year 2020 (California Legislative Counsel 2006). This policy package, typically known by its legislative designation as Assembly Bill 32 (AB 32), is more ambitious in percentage terms than the Federal climate legislation – the Waxman-Markey bill – that passed the U.S. House of Representatives in 2009, but failed to make it through the U.S. Senate. The California policy includes: energy efficiency standards for vehicles, building, and appliances; renewable portfolio standards for electricity generation that increase from 20% to 33%; a low carbon fuel standard; and a cap-and-trade system (California Environmental Protection Agency, Air Resources Board 2014).

The AB 32 cap-and-trade system covers 85% of the California economy (as of January 2015), with the cap declining through 2020 in order to bring about emissions reductions. The system includes increasing uses of auctions over time, a price collar that essentially creates a hybrid of cap-and-trade and tax, and provisions for the protection of trade-sensitive industries.

The design, enactment, and implementation of the cap-and-trade system provide some valuable lessons. First of all, carbon pricing is necessary, but not sufficient, due to the presence of other market failures, such as the principal-agent problem associated with renter–occupied properties. This is an example of how specific non-pricing policies can be complementary to a carbon-pricing regime.

But some "complementary policies" conflict rather than complement (Goulder and Stavins 2011). In California, this is the case with the Low Carbon Fuel Standard (LCFS) policy and with the renewable electricity standards. In the presence of a cap-and-trade regime, such additional policies reduce emissions in the targeted sector, but those emissions reductions are undone by increasing emissions in other sectors, as a result of allowance sales. Hence, the consequences of such "complementary policies" targeting sources already covered by a cap of a cap-and-trade system are: (1) no incremental CO_2 emissions reductions are achieved – instead, emissions are simply relocated; (2) abatement costs in aggregate are driven up, because marginal costs are no longer equated; and (3) allowance prices are suppressed, because overall demand for allowances is reduced. So, many so-called "complementary policies" are nothing of the kind. This is not only a problem in California. It is also a major problem in Europe (Stavins 2012).

Other lessons include the fact that the initial free allocation of allowances fostered political support. Although there are sound economic arguments for auctioning allowances, and then using the auction revenue to cut distortionary taxes, and thereby reducing the overall social cost of the program (Goulder 1995), the initial free allocation was essentially good politics.

Also, the system's performance has demonstrated that an economy-wide system is feasible, as well as more effective and much more cost-effective than a sectoral system. And the price collar, which essentially rendered the cap-and-trade system a hybrid of cap-and-trade and a carbon tax, has been effective.

There is one final lesson from California's experience with its cap-and-trade system, which is important because it is linked with a central political concern about any climate policy: the effects of the policy on economic competitiveness. This is a reasonable concern, because a policy that drives up the cost of producing goods and services within one jurisdiction (in proportion to their carbon intensity) would naturally render those goods and services less competitive compared with products that are produced in jurisdictions without such policies in place.

It turns out that although this is a common political concern, it is of less importance economically, partly because it applies only to a limited set of sectors with highly carbon-intensive production. However, because it is a key political concern, policies have frequently been put in place to address these competitiveness concerns as part of cap-and-trade (as well as other climate policies). In the cap-and-trade context, the approach to addressing competitiveness concerns has typically been to allocate the allowances for free, rather than selling them.

What is the effect of such free allocation of allowances on competitiveness? The answer is that it accomplishes nothing. It does make the firms that receive the free allowances quite happy, of course, because the allowances are as good as cash. They are worth thousands or even millions of dollars on the market. But because the free allocation is inframarginal, it has no effect on competitiveness. A firm's marginal cost of production is not affected. It receives the free allowances, puts the money in the bank, but the incentive to relocate its production or to locate future investments in other jurisdictions remains unchanged.

On the other hand, by making the allowance allocation contingent on production it can be made marginal, rather than inframarginal, and thereby can reduce competitiveness effects. This is, in fact, what is done in the California system with its "output–based updating allocation" system, which makes the allocations marginal. So, in the California system, competitiveness risks and related leakage risks are reduced for trade-sensitive sectors. However, significant leakage risks remain for the electricity sector, due to contract reshuffling (Bushnell, Peterman, and Wolfram 2008). Ultimately, the only way to eliminate competitiveness risks altogether is through broader national and international coalitions of action.

The National Context

Carbon pricing is a very sensitive political issue, particularly in the United States. Why? For one thing, it makes costs transparent, unlike conventional policy instruments, which tend to hide their costs. From an economic perspective, it is highly desirable to make the costs of policies and products transparent, but from a political perspective, this is a great disadvantage. Conservative opponents of climate policy in the U.S. Congress found it easy to associate cap-and-trade with the T-word. Indeed, cap-and-trade was successfully demonized as "cap-and-tax" (Schmalensee and Stavins 2013).

Antipathy by conservatives to cap-and-trade systems is ironic, given past experience with the development and implementation of these policies. President Ronald Reagan developed and implemented through his EPA, the leaded gasoline phasedown using cap-and-trade. President George H. W. Bush developed and implemented the sulfur dioxide allowance trading program to cut acid rain by half, as part of the Clean Air Act Amendments of 1990. And President George W. Bush proposed the Clean Air Interstate Rule, which used a cap-and-trade system to cut sulfur dioxide emissions by an additional 70%.[2] In Congressional debates about climate policy, cap-and-trade was collateral damage in the battle against climate action, which itself was a consequence of the severe political polarization that has increasingly characterized the U.S. Congress (Stavins 2011b).

Does this mean there will be no U.S. climate policy? No, because, in fact, there already is U.S. climate policy in place, and much more has been proposed.

2 That rule was subsequently invalidated by the courts, for reasons not associated with the cap-and-trade mechanism *per se* (Schmalensee and Stavins 2013).

The U.S. Supreme Court, EPA, and the Clean Air Act

There has been a cascade of policy, beginning with a 2007 U.S. Supreme Court decision in Massachusetts v. EPA, which required EPA to consider regulating mobile sources of CO_2. This led to EPA's Endangerment Finding in 2009, which affirmed that CO_2 endangers public health and welfare. This, in turn, required EPA to regulate mobile sources of CO_2 emissions, a requirement that the Obama administration met through more stringent Corporate Average Fuel Economy (CAFE) standards. That action defined carbon dioxide as a pollutant under the Clean Air Act, and thereby led to EPA's subsequent proposals of regulation of CO_2 emissions from the electricity sector, both for new and existing sources.

The rule affecting new power plants was proposed on September 20, 2013, and will, when finalized, have the effect of essentially ruling out the construction of new coal-fired power plants, unless they capture and store their CO_2 emissions, using so-called carbon capture and storage (CCS) technology. But the rule will have virtually no impact, because even without the rule, no new coal-fired power plants were planned or even contemplated, as a result of the low price of natural gas (from unconventional sources) relative to the price of coal.

Much more important is the rule for existing electric power plants, the Clean Power Plan, which was proposed on June 2, 2014, and which would reduce CO_2 emissions from the electricity sector by 30% below their 2005 level by the year 2030 (Fowlie, et al. 2014). If the final rule (expected in June, 2015) survives legal challenge, it will facilitate cost-effectiveness through its provisions for flexibility, but will the rule be efficient? That is, will it maximize welfare? Welfare maximization is a difficult criterion to meet, and so we can ask a more modest question: is the rule likely to enhance welfare, that is, will its benefits exceed its costs?

An Economic Analysis of the Clean Power Plan

This is a good point at which to remind ourselves that GHGs mix globally in the atmosphere, and so damages are spread around the world and are unaffected by the location of emissions. This means that any jurisdiction taking action – a region, a country, a state, or a city – will incur the direct costs of its actions, but the direct climate benefits (avoided damages of climate change) will be distributed globally. Hence, the direct climate benefits a jurisdiction reaps from its actions will inevitably be less than the costs it incurs, despite the fact that global climate benefits may be greater – possibly much greater – than global costs.

EPA released its 376-page Regulatory Impact Analysis (RIA) of the proposed Clean Power Plan rule the same day it released the 645-page proposed rule itself (U.S. Environmental Protection Agency 2014). An RIA is essentially a benefit-cost analysis, required for significant new Federal rules by a series of Executive Orders going back to the presidency of Jimmy Carter, and reaffirmed by every President since, including most recently President Obama.

Given the fundamental economic arithmetic of a global commons problem, it would be surprising – to say the least – if EPA were to find that the expected benefits of the proposed rule would exceed its expected costs, but this is precisely what EPA found. Indeed, its central estimate is of positive net benefits (benefits minus costs) of $67 billion annually in the year 2030 (employing a mid-range 3% discount rate). How can this be?

First, EPA does not limit its estimate of climate benefits to those received by the United States (or its citizens), but uses an estimate of global climate benefits. Second, in addition to quantifying the benefits of climate change impacts associated with CO_2 emissions reductions, EPA quantifies and includes (the much larger) benefits of human-health impacts associated with reductions in other (correlated) air pollutants.

U.S. versus Global Damages

There are surely ethical arguments (and possibly legal arguments) for employing a global damage estimate – as opposed to a U.S. damage estimate – in a benefit-cost analysis of a U.S. climate policy (Gayer and Viscusi 2014), but until recently all Regulatory Impact Analyses (RIAs) had focused exclusively on U.S. impacts.

In the context of a conventional RIA, it does seem strange – at least at first blush – to use a global measure of the benefits of a U.S. regulation. If this practice were applied in a consistent manner – that is, uniformly in all RIAs – it could result in some quite bizarre findings. For example, a Federal labor policy that increases U.S. employment while cutting employment in competitor economies might be judged to have zero benefits. As another example, under global accounting, if a domestic climate policy had the unintended consequence of causing emissions and economic leakage (through relocation of some manufacturing to other countries), that would not be considered a cost of the regulation (and with diminishing marginal utility of income, it might be counted as a benefit).

However, a counter-argument to this line of thinking is that the usual, narrow U.S.-only geographic scope of an RIA is simply inappropriate for a global commons problem. Otherwise, we would simply restate in economic terms the free-rider consequences of a global commons challenge. In other words, a domestic-only RIA of a climate policy could have the effect of "institutionalizing free riding."[3]

I leave it to legal scholars and lawyers to debate the law, and I defer to the philosophers to debate the ethics. Instead, we can ask what the consequences would be for EPA's analysis if a U.S. climate benefits number was used, rather than a global number. For this purpose, we can start with EPA's estimates (from its RIA of the proposed rule[4]) of 2030 benefits and costs, using a mid-range 3% real discount rate. The estimated (global) climate benefits of the rule are $31 billion.

In order to think about what the domestic climate benefits might be, we can turn to the Obama administration's original calculation of the "social cost of carbon" in 2010 (Interagency Working Group on Social Cost of Carbon 2010), where the Interagency Working Group estimated a central global value for 2010 of $19 per ton of CO_2, and noted that U.S. benefits from reducing GHG emissions would be, on average, about 7 to 10 percent of global benefits across the scenarios analyzed with the one model that permitted such geographic disaggregation.[5]

Taking the midpoint of the Obama Working Group's 7-10% range, U.S. damages (benefits) may be estimated to be 8.5% of global damages, which would reduce the $31 billion reported in the RIA to about $2.6 billion, which is considerably less than the RIA's estimated total annual compliance costs of $8.8 billion (assuming all states facilitate cost-effective actions). This validates the intuition that for virtually any jurisdiction, the direct climate benefits it reaps from its ac-

3 Of course, if global benefits are to be included in a regulatory assessment, it can be argued that global costs (such as leakage) should also be considered.

4 See Table ES-7 on page ES-19 and Table ES-10 on page ES-23 of U.S. Environmental Protection Agency 2014.

5 The Interagency Working Group also suggested that if climate damages are simply proportional to GDP, then the U.S. share would be about 23%. However, given the reality of highly unequal geographic distribution of climate change effects worldwide (IPCC 2013), combined with the exceptionally heterogeneous nature of climate sensitivity among the world's economies, which vary from those with trivial reliance on agriculture to those dominated by their agricultural sectors (IPCC 2014a), the justification for the second approach is not compelling.

tions will be less than the costs it incurs (again, despite the fact that global climate benefits may be much greater than global costs).

There are abundant caveats on both sides of this simple analysis. One of the most important is that if the proposed U.S. policy were to increase the probability of other countries taking climate policy actions (which is likely the case), then the impacts on U.S. territory of such foreign policy actions would merit inclusion even in a traditional U.S.-only benefit-cost analysis. More broadly, although it has been traditional to use a U.S.-only benefits measure in RIAs, the current guidelines for carrying out these analyses from the Office of Information and Regulatory Affairs of the U.S. Office of Management and Budget (Circular A-4) requires that geographic U.S. benefit and cost estimates be provided, but also allows for the optional inclusion of global estimates (U.S. Office of Management and Budget 2003).

Pending resolution (or more likely, discussion and debate) from lawyers and philosophers regarding the legal and ethical issue of employing domestic benefits versus global benefits in a climate regulation RIA, it is very important to recognize that there is an even more important factor that explains how EPA came up with estimates of significant positive net benefits (benefits exceeding costs) for the proposed rule (and would even if a domestic climate benefits number were employed), namely, the inclusion of (domestic) health impacts of other air pollutants, the emissions of which are correlated with those of CO_2.

Correlated Pollutants and Co-Benefits

The proposed regulation to reduce CO_2 emissions from the electric power sector is intended to achieve its objectives through a combination of less electricity generated (compared with a business-as-usual trajectory), greater dispatch of electricity from less CO_2-intensive sources (natural gas, nuclear, and renewable sources, instead of coal), and more investment in low CO_2-intensive sources. Hence, it is anticipated that less coal will be burned than in the absence of the regulation (and more use of natural gas, nuclear, and renewable sources of electricity). This means not only less CO_2 being emitted into the atmosphere, but also decreased emissions of correlated local air pollutants that have direct impacts on human health, including sulfur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM), and mercury (Hg).

It is well known that higher concentrations of these pollutants in the ambient air we breathe – particularly smaller particles of particulate matter (PM2.5) – have very significant human health impacts in terms of increased risk of both morbidity and mortality (Driscoll, et al. 2014). The numbers dwarf the climate impacts themselves. Whereas the U.S. climate change impacts of CO_2 reductions due to the proposed rule in 2030 are probably less than $3 billion per year (see above), the health impacts (co-benefits) of reduced concentrations of correlated (non-CO_2) air pollutants were estimated by EPA to be some $45 billion/year (central estimate).[6]

The Bottom Line

The combined U.S.-only estimates of annual climate impacts of CO_2 ($3 billion) and health impacts of correlated pollutants ($45 billion) greatly exceed the estimated regulatory compliance costs of $9 billion/year, for positive net benefits amounting to $39 billion/year in 2030. This is the key argument related to the economic efficiency of the proposed rule from the perspective of U.S. welfare. If EPA's global estimate of climate benefits ($31 billion/year) is employed instead, then the rule looks even better, with total annual benefits of $76 billion, leading to EPA's bottom-line estimate of positive net benefits of $67 billion per year. See the summary in Table 1.

Thus, the Obama Administration's proposed regulation of existing power-sector sources of CO_2 has the potential to be cost-effective, and it can also be welfare-enhancing, if not welfare-maximizing. Proponents of the Administration's proposed rule are likely to take this assessment of EPA's Regulatory Impact Analysis as evidence of the sensibility of the rule, and opponents of the Administration's proposed actions are likely to claim that my assessment of the RIA provides evidence of the foolishness of EPA's proposal. So it is in our pluralistic system.

6 This assumes that the co-benefits estimated by EPA are based upon a comparison with a business-as-usual baseline that includes the effects of all existing EPA and state regulations for these same local air pollutants.

A View of the International Domain: Placing Climate Negotiations in Perspective

The frequently-heard cliché about the baseball season applies even more to international climate change policy: it is a marathon, not a sprint. Here are four reasons why.

First, scientifically, what matters is the stock of carbon in the atmosphere, not how much we emit at any given point in time. The damages from climate change are linked with concentrations, not with emissions per se (IPCC 2013). The stock of CO_2 in the atmosphere is like a bathtub that fills up as water continues to flow from the spout. But this atmospheric bathtub has a very slow drain, as it takes decades to centuries for greenhouse gases to precipitate out of the atmosphere (mainly as oceans slowly absorb CO_2).

Second, economically, virtually all sound analyses have found that the cost-effective path of climate action will involve a gradual tightening of emissions target globally so as not to unnecessarily render (fossil-fuel burning) infrastructure prematurely obsolete (IPCC 2014b). In other words, an affordable climate policy will not outlaw the use of current carbon-intensive technologies, but will provide incentives (or possibly requirements) for the adoption of more carbon-friendly technologies as we renew our infrastructure and machinery. It would be absurdly costly to confiscate and destroy our gasoline-powered cars today and force individuals to purchase zero-emission vehicles. Rather, it makes economic sense to put in place policies that increase the likelihood that our next car will be significantly more fuel-efficient, if not carbon-neutral.

Third, technological change (innovation) will be key to bringing down the costs of fighting climate change in the long term, both for economic rationality and political feasibility. Companies will only develop and adopt low-carbon technologies in response to long-term price signals (Jaffe, Newell, and Stavins 2002).

Fourth, administratively, the creation of durable international institutions will be essential. The climate challenges the world faces today are at least as great as the challenges faced by world leaders when they gathered in Bretton Woods, New Hampshire in 1944 to establish international monetary and financial order after World War II. Five decades were required to develop and solidify the World Bank, the International Monetary Fund, and the World Trade Organization. A new international climate regime will not be effective overnight.

For all of these reasons, international climate negotiations will be an ongoing process – not a single task with a clear end-point. Climate negotiations should aim at progress towards the foundation for meaningful long-term action, rather than focusing on an unattainable immediate "solution."

The challenge presented by the long-term character of the climate problem is immense. Politicians in representative democracies have strong incentives to appeal to today's voters by giving them benefits that will be financed by future generations. The climate challenge calls for precisely the opposite – today's citizens agreeing to costly actions that will protect future generations.

Searching for the Path Forward

For the past seven years, I have directed the Harvard Project on Climate Agreements, the mission of which is to help identify the key design elements of a scientifically sound, economically rational, and politically pragmatic international policy architecture for global climate change. The Project draws upon ideas from leading thinkers around the world from academia (economics, political science, law, and international relations), private industry, governments, and nongovernmental organizations (NGOs). This has included more than 50 research initiatives in Argentina, Australia, China, Europe, India, Japan, and the United States.

Four major lessons have emerged from the three books and more than 75 discussion papers, viewpoints, and policy briefs that the Project has published. First, market-based approaches to public policies will be essential.

Second, getting carbon prices right will be necessary, but not sufficient. This is because of other market failures that exist, such as the public-good nature of research and development (R&D). It is well known that because of the spillovers of information that results from innovative activity, the private sector tends to systematically underinvest in basic R&D activity. This raises the need for effective, direct technology policies, such as government funding of private sector R&D.

Third, "developing country" participation will be essential. It will be impossible to address climate change without meaningful participation by the key emerging economies. Even if all countries in the "industrialized world" – the countries belonging to the Organization for Economic Cooperation and Development (OECD) – were to reduce their emissions to zero, global emissions would still increase, because increases in emissions are coming from the large emerging economies of China, India, Brazil, South Korea, Mexico, South Africa, and Indonesia. Therefore, a central task in international negotiations is developing the means to bring these key emerging economies on board.

Fourth and finally, the de facto post-2020 international policy architecture may already be emerging, namely, the direct and indirect linkage of regional, national, and sub-national cap-and-trade and other policy instruments (Ranson and Stavins 2013; Bodansky, Hoedl, Metcalf, and Stavins 2014).[7]

Thinking about the International Climate Negotiations

Two fundamental realities – the global commons nature of the problem plus its long-term character – present fundamental geopolitical challenges. Twenty years ago, when 172 governments met in Rio de Janeiro, Brazil, for the original "Earth Summit", they agreed on a legally binding framework for climate policies, the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations 1992), and established two key principles. One was the goal of "stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic [manmade] interference with the climate system." The other principle defined how this goal should be pursued: "The Parties [to the UNFCCC] should protect the climate system … on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities" (United Nations 1992).

This second principle signalled the conviction that although the climate problem is a global commons issue, with all countries contributing, some countries had contributed more to the stock of emissions in the atmosphere than others – and those countries were the wealthier countries of the world. Hence, a specific set of industrialized countries (listed in Annex I of the Convention) were committed to take actions "with the aim of returning [their greenhouse gas emissions] individually or jointly to their 1990 levels" (United Nations 1992).

When the members of the UNFCCC met for the first follow-up meeting in 1995 in Berlin, they agreed that "common but differentiated responsibilities" meant that only the industrialized countries listed in Annex I would commit to emission reductions. The developing countries not listed in Annex I would take on no such commitments. This so-called Berlin Mandate was then codified with numerical national targets and timetables in the 1997 Kyoto Protocol (United

7 For a comprehensive, up-to-date survey of the scholarly literature from economics, political science, international relations, and law, see: Stavins, *et al.* 2014.

Nations 1997). It opened up a dramatic gap between rhetoric and reality (Aldy and Stavins 2012a).

By the time of the Berlin Mandate, the developing countries already emitted more greenhouse gases every year than the well-to-do countries listed in Annex I (World Resources Institute 2012). See Figure 1. Even in terms of emissions per capita, they were not far behind. By 2005, when the Kyoto Protocol entered into force, almost 50 of the non-Annex I countries had per capita fossil fuel CO_2 emissions that were higher than those of the lowest-emitting Annex I country (U.S. Energy Information Administration 2012).

In the end, the Kyoto Protocol failed to constrain the world's six largest greenhouse gas emitters; either because they were still classed as developing countries and therefore did not take on commitments (China, India, Brazil, and Indonesia), or because they failed to ratify the Protocol (United States), or because they ratified it but adopted only a non-binding emissions target (Russia).

Since 1990, the base year of the Kyoto Protocol, emissions have grown by approximately 5 percent annually in the non-Annex I countries, while remaining about flat in the Annex I nations (U.S. Energy Information Administration 2012). Furthermore, the split into countries with commitments and those without has made fighting climate change much more expensive: it has effectively quadrupled the global cost of emission cuts that are necessary to stabilize atmospheric concentrations of greenhouse gases, relative to a cost-minimizing scenario (Nordhaus 2008).

But prospects for change began to emerge in 2009, when the UNFCCC members met in Copenhagen, Denmark, and a year later in Cancun, Mexico. The agreements they reached began to blur the distinction between Annex I and non-Annex I.

They departed even further from the distinction between developed and developing countries at their meeting in Durban, South Africa, in 2011. Here they agreed on a structure that would entail the participation of all parties in the effort to mitigate greenhouse gas emissions (United Nations 2011). Under the "Durban Platform for Enhanced Action," delegates agreed to craft a future legal regime that would be "applicable to all Parties ... under the Convention." This promised the potential to essentially eliminate the Annex I/non-Annex I distinction, and thereby be an important step toward breaking the logjam that has prevented progress. All eyes are now on the Paris climate conference scheduled for the end of 2015.

International cooperation is necessary for fighting climate change, but fully global action is not. The reality is that 16 countries and regions (counting the European Union as one) account for approximately 80 percent of global emissions. And two countries stand out as the greatest current – and historical – contributors: China, estimated to account for 29 percent of global CO_2 emissions in 2012; and the United States, with 15 percent of the estimated global total in that year. Next in line are the 27 countries of the European Union (12 percent), India (6 percent), Russia (5 percent), and Japan (4 percent). With the top two contributors accounting for nearly half of all emissions, attention has understandably focused on China and the United States.

Chinese Developments

The prognosis for meaningful, economy-wide climate policy in China is similar to the U.S. case. There are positive developments in China on several fronts. China may achieve its goal of reducing the carbon intensity of its economy 45 percent below the 2005 level by 2020, but China's coal consumption and total CO_2 emissions are expected to continue to increase (International Energy Agency 2014).

Much has been written in the western press about the Chinese government's concern about worsening local air pollution – the mix of particulates, ozone, sulphur, and nitrogen oxides that hang over Beijing and other cities (Economist 2014). Pollution has been growing gradually, but daily and hourly peak levels – particularly of particulates – have been increasing more rapidly, with hourly concentrations in Beijing now having exceeded the worst experienced in Los Angeles in the 1960s by more than ten times (Zhang, Wong, and Lee 2015).

China's burgeoning middle-class has begun to demand action to improve air quality, partly facilitated by the spread of social media, and government statements have begun to respond to this pressure. Prime Minister Li Keqiang opened the 2014 session of the National People's Congress with a resounding declaration of war on environmental pollution, warning about the downside of the rapid and unconstrained economic development China had enjoyed (Economist 2014).

Emissions of many of the local air pollutants – including from coal-fired power plants, industrial facilities, and motor vehicles – are correlated with emissions of CO_2 from the same sources. Hence, actions aimed at improving air quality will also likely curb CO_2 emissions (although in some cases, CO_2 and local air pollutants are substitutes, not complements, as in the case of using coal gasification to produce clean-burning methane).

Convergence of U.S. and Chinese Perspectives

China and the United States have engaged in debates on climate change regarding the fundamental question of who should do what. They and their respective allies in the developing and developed worlds have clashed over the call under the Durban Platform for a global climate deal that is "applicable to all Parties … under the Convention". The United States and other industrialized countries insist that this calls for an agreement that brings about emissions reduction pledges by all countries. In particular, they understand it to include industrialized countries plus the large emerging economies.

But China, India, and most countries in the developing world, have pointed out that the Durban Platform was adopted under the auspices of the UNFCCC, with its key principle of "common but differentiated responsibilities" – the idea that rich countries should bear a greater share of the burden of tackling climate change – as well as the subsequent mandate calling for emissions reductions only by developed (Annex 1) countries. Therefore, they have said, the Durban Platform calls only for emission reduction commitments from the industrialized nations.

In the midst of this frustrating finger-pointing, there are reason for cautious optimism – namely bilateral discussions on climate change policy between China and the United States. Such bilateral negotiations between China and the U.S. – possibly outside of the UNFCCC – may be where real progress is made. When this happens, it will largely be because of an emerging convergence of interests.

First, the annual CO_2 and greenhouse gas emissions of these two countries have converged. While America's CO_2 emissions in 1990 were almost twice the level of Chinese emissions, by 2006 China had overtaken the United States (Figure 2). These are the world's two largest emitters (World Bank 2014).

Second, cumulative emissions are particularly important, because it is the accumulated stock of greenhouse gases in the atmosphere that cause climate change. Any discussion of distributional equity in the climate realm therefore inevitably turns to considerations of "historic responsibility." Looking at the period 1850-2010, the United States led the pack, accounting for nearly 19 percent of cumulative global emissions of greenhouse gases, with the European Union in second place at 17 percent, and China third, accounting for about 12 percent of global cumulative emissions (World Bank 2014). But that picture is rapidly changing.

Emissions are flat to declining throughout the industrialized world, while increasing rapidly in the large emerging economies, in particular China. Depending on relative rates of economic growth, China may top all countries in cumulative emissions within ten to 20 years.

Third, China and the United States both have historically relied mostly on coal for generating electricity – and both are trying to do something about it. At a time when U.S. dependence on coal is decreasing (largely due to increased supplies of natural gas and hence lower gas prices), China continues to rely on this dirty fuel (International Energy Agency 2014). But China's concern about the health impacts of local air pollution may lead it to wean itself away from coal. Importantly, both countries have very large shale gas reserves. U.S. output (and use for electricity generation) has been increasing rapidly, bringing down CO_2 emissions. Chinese exploitation has been constrained by available infrastructure – it lacks pipelines – but that will change.

Fourth, both countries have been moving forward with policies that explicitly address greenhouse gas emissions, and in both countries these have featured sub-national market-based policy instruments – in particular, cap-and-trade systems. In China, the government has launched local and regional CO_2 cap-and-trade systems in Shenzhen, Shanghai, Guangdong, Beijing, Tianjin, Hubei, and Chongqing (Liu 2014). In the United States, California's ambitious AB-32 cap-and-trade system continues to make progress, while in the northeast, the Regional Greenhouse Gas Initiative (RGGI) is witnessing higher allowance prices due to more severe targets recently adopted by the nine participating states (RGGI 2014).

Fifth, CO_2 policy action is also imminent at the national level in both countries. In China, the government has stated its intention to link its local and regional CO_2 cap-and-trade systems together in a nationwide system. In the United States, the failure in 2009 of meaningful carbon-pricing policy in the Congress has led the Obama Administration to turn to regulatory action, including its June 2014 announcement of proposed CO_2 regulations for existing power plants. It is striking that just as CO_2 emissions reductions in China are most likely to be achieved as by-products of policies targeting particulates and other local air pollutants, the Obama administration's economic analysis of its proposed CO_2 limits on power plants justifies the costs of those limits by appeal to the health benefits of reductions in correlated local air pollutants.

Sixth and finally, there is the reality of global geopolitics. If the twentieth century was the American Century, then many observers, including leaders in China, anticipate (or at least hope) that the twenty-first century will be the Chinese Century, one of global leadership, not obstruction (Jolly and Buckley 2013).

For all these reasons, there should be no surprise that on November 12, 2014, Chinese President Xi Jinping and U.S. President Barak Obama issued a joint announcement of expanded cooperation on climate change mitigation, including new U.S. emission-reduction targets for 2025, and – for the first time – a commitment from China to cap its emissions by 2030 or earlier, after which they would decline.[8]

The Path Ahead

The political climate in the United States presents its own challenges to progress. Indeed, it will take a great deal of dedicated effort – and profound luck – to find political openings that can bridge the wide partisan divide that exists on climate change policy and environmental issues more broadly.

Think about the following. Nearly all major U.S. environmental laws were passed in the wake of highly publicized environmental events or "disasters," such as the spontaneous combustion of the Cuyahoga River in Cleveland, Ohio, in 1969, and the discovery of toxic substances at Love Canal in Niagara Falls, New York, in the mid-1970s. But the day after the Cuyahoga River caught fire, no press reports commented that the cause was uncertain, that rivers periodically catch on fire from natural causes. On the contrary, it was immediately apparent that the cause was waste dumped into the river by local industry. A direct consequence of the observed "disaster" was, of course, the Clean Water Act of 1972.

But climate change is distinctly different. Unlike the environmental threats addressed successfully in past U.S. legislation, climate change is essentially unobservable to the general population. We observe the weather, not the climate. Until there is an obvious, sudden, and perhaps cataclysmic event – such as a loss of part of the Antarctic ice sheet leading to a dramatic sea-level rise – it is unlikely that U.S. public opinion will provide the tremendous bottom-up demand that inspired previous national action on the environment.

8 All of the text above regarding China-U.S. convergence on climate change (with the exception of the single paragraph describing the November 2014 announcement by Presidents Xi and Obama) was written prior to the joint announcement.

That need not mean that there can be no truly meaningful, economy-wide climate policy until disaster has struck. But it does mean that bottom-up popular demand may not come in time, and that instead what will be required is inspired leadership at the highest level that can somehow begin to bridge the debilitating partisan political divide.

Parting Words

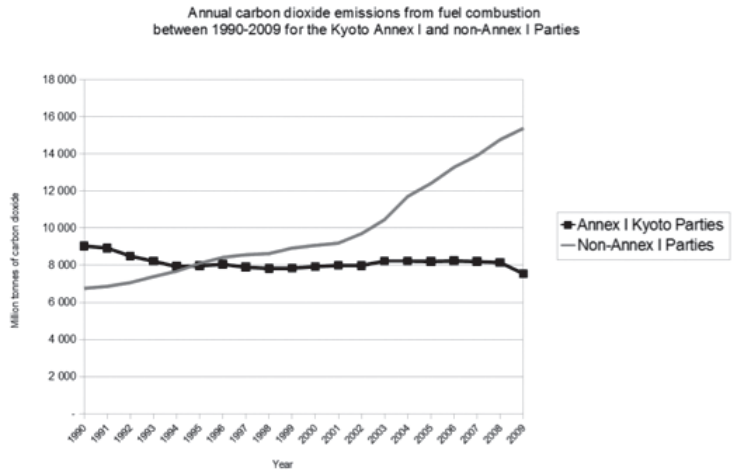
As I hope I have illustrated, environmental economics is not an oxymoron – an internal contradiction. Far from it, an economic perspective is absolutely essential for a full understanding of environmental problems. Therefore, economic analysis is nothing less than key for the design of solutions that will be environmentally effective, economically sensible, and politically pragmatic. That has been the common theme of all of the sessions in which I participated at Beloit College as the 2014 Upton Scholar, a week that I will not forget.

Table 1:
Estimated Benefits and Costs of EPA's Proposed Clean Power Plan Rule in 2030
(Mid-Point Estimates, Billions of Dollars)

	Climate Change Impacts		Health Impacts (Co-Benefits) of Correlated Pollutants plus …	
	Domestic	Global	Domestic Climate Impacts	Global Climate Impacts
Benefits				
Climate Change	$ 3	$ 31	$3	$31
Health Co-Benefits			$45	$45
Total Benefits	$ 3	$ 31	$48	$76
Total Compliance Costs	$ 9	$ 9	$ 9	$ 9
***Net Benefits** (Benefits – Costs)*	**- $ 6**	**$ 22**	**$ 39**	**$ 67**

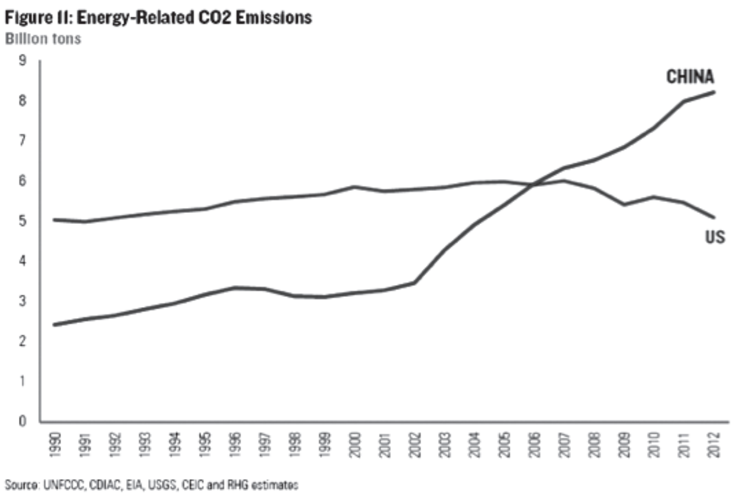
Source: Interagency Working Group on Social Cost of Carbon 2010; IPCC 2013; IPCC 2014a; U.S. Environmental Protection Agency 2014. Reproduced from Stavins 2014.

Figure 1



Source: Wikimedia Commons 2014.

Figure 2



Source: Rhodium Group, 2013.

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Markets and the Environment: Progress and Future Challenges

Sheila M. Olmstead[1]

1.0 Introduction

A major contribution of the field of environmental economics, the theory of pollution control, is rooted in the work of Pigou (1920), but was sketched out in earnest during the past several decades. Influenced by the contributions of Coase (1960), economists worked out the basic principles of emissions trading and demonstrated its cost-effectiveness relative to regulatory approaches relying on technology standards and uniform performance standards, known collectively as "command-and-control" (CAC) policies (Dales 1968, Montgomery 1972, Baumol and Oates 1988, Hahn and Stavins 1992). Further development of the Pigouvian principles of environmental taxation was a part of this trend, as well (Baumol 1972, Baumol and Oates 1971), and important theoretical contributions to the development of emissions tax approaches accelerated during the 1990s (Bovenberg and de Mooij 1994, Bovenberg and Goulder 1996).

These tools have also moved from theory to practice in important and diverse public policy applications including local and regional air and water pollution control, solid waste disposal, land preservation, fisheries management, and mitigation of the greenhouse gas emissions that are changing the global climate. This is remarkable progress, given where the modern U.S. environmental regulatory apparatus began, with a Clean Air Act that forbids the consideration of costs in air quality standard-setting, a Clean Water Act that had as its original goal the elimination of all pollution emissions to water, and other elements of statutory design that would seem to hamper the application of the efficiency criterion,

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or even consideration of cost-effectiveness in the choice of environmental policy instruments.

On the other hand, market-based policy instruments represent a small fraction of the corpus of environmental regulation, and in recent years, some of these approaches have become increasingly politically contentious, even among political communities that initially embraced them. Thus, for those who believe that the market failures at the root of pollution and other examples of environmental degradation are best addressed using market principles, the glass in 2015 may be either half full, or half empty.

Section 2 of this paper outlines some key principles of market-based environmental policy—the theoretical contributions of environmental economists. Section 3 describes the efforts of academic economists to provide a bridge between theory and practice, communicating academic ideas and evidence to policymakers and, in some cases, contributing directly to policy design. Section 4 discusses several of the most significant applications of market-based policy to real-world environmental problems. Section 5 identifies key challenges to expanding the reach of markets in environmental policy, and Section 6 concludes.

2.0 Principles of Market-Based Environmental Policy

Until recently, the standard approach to environmental regulation included almost exclusively an array of policy instruments that economists refer to as "command-and-control" (CAC) or prescriptive approaches, which regulate the behavior or performance of individual facilities. Prescriptive approaches comprise two general classes: technology standards and performance standards. A technology standard requires firms to use a particular pollution abatement technology. For example, the 1977 Clean Air Act Amendments required new power plants to install large flue-gas desulfurization devices ("scrubbers") to remove sulfur dioxide (SO_2) from stack gases. A performance standard allows polluters more leeway in the choice of control technology, imposing a ceiling on total emissions in a period (for example, tons per year), or a maximum allowable emissions rate (for example, pounds of pollution per unit of output produced, or per unit of fuel consumed).

In contrast to prescriptive approaches, market-based policy instruments (MBIs) are decentralized, focusing on aggregate or market-level outcomes, such as ambient pollution levels or total emissions, rather than the activities of individual facilities. Economic theory strongly favors market-based over CAC policy instruments, because market-based policy instruments are more cost-effective.[2] A cost-effective environmental policy instrument is one that can achieve a given environmental standard at least cost, even if the standard is either more or less stringent than the efficient standard. Next to efficiency, cost-effectiveness is arguably the most important economic criterion for comparing two environmental policies.

2.1 Taxes and Tradable Permits: Cost-Effective Policy Instruments[3]

The classic economic prescription is to tax negative externalities, with the efficient tax equal to the marginal damages at the efficient level of the externality (Pigou 1920, Baumol 1972, Sandmo 1975). In response to a tax, regulated firms have two choices for each unit of pollution they would have emitted in the absence of regulation – they can continue to emit that unit, paying the tax, or they can incur abatement costs for that unit. Thus, each firm will reduce emissions just to the point at which the marginal cost of emissions abatement is equal to the unit tax on emissions. Since each firm equates the cost of abatement with the tax, marginal abatement costs are equal across firms, generating the least-cost allocation of emissions reductions.

A later contribution by Ronald Coase recognized the fundamental symmetry of externalities. Coase (1960) noted that the direction of compensation for externalities was not prescribed by the efficiency criterion, and that under certain restrictive conditions, private negotiation could induce efficient outcomes. Coase's focus on property rights facilitated the development of systems of marketable pollution permits, known as "cap-and-trade" systems (Dales 1968, Montgomery 1972).[4] Under cap-and-trade, the regulator sets an aggregate cap on pollution and allocates emissions permits to the regulated community, either gratis or by

2 CAC policy instruments are not all equal in economic terms. For example, performance standards are generally better than technology standards at minimizing the sum of emissions control costs and pollution damages (Besanko 1987). Even within the category of performance standards, some are better than others in terms of their effectiveness and cost-effectiveness (Helfand 1991).

3 Other policy instruments fall within the category of market-based approaches. For example, the reduction or elimination of environmentally-damaging subsidies is a market-based approach to environmental policy, as are deposit-refund systems (Stavins 2003).

4 Dales (1968) refers to a system of tradable permits for emissions; Montgomery (1972) refers to a system of tradable permits for pollution concentrations in an airshed or waterbody. Most existing tradable permit systems are modeled on the former.

auction. The pollution permits are transferable, and each firm will buy and sell permits based upon a comparison of market permit prices with its own marginal abatement costs. When the permit market clears, each firm equates its own marginal pollution abatement cost with the permit price, minimizing the cost of control to meet the aggregate cap (Tietenberg 2006).

An appealing aspect of cap-and-trade is that, in theory, the ability of such a policy to arrive at the least-cost allocation of responsibility for emissions abatement across regulated firms is independent of the initial allocation of permits. This means, for example, that initial permit allocations may be manipulated to accomplish distributional outcomes that build sufficient political support for new or more stringent environmental regulations (Joskow and Schmalensee 1998); or to meet income re-distribution goals or exogenous "fairness" criteria, as has been suggested for the establishment of an international carbon emissions trading regime (Olmstead and Stavins 2012).[5]

The principle that taxes and tradable permits are more cost-effective than CAC policies in the short-run is well-developed in economic theory (Crocker 1966, Baumol and Oates 1971, Bohm and Russell 1985, Tietenberg 1990, Hahn and Stavins 1992, Stavins 2003). MBIs take advantage of abatement cost differences across regulated firms. The firms with the lowest abatement costs exercise the most control, and those with the highest costs exercise the least control (paying more for permits or higher tax bills).[6]

The greatest potential cost savings from these types of environmental policies may be achieved in the long run, however, when firms' abatement technologies are not fixed. Because they require firms to pay to pollute, MBIs provide strong incentives for regulated firms to invest in new technologies that reduce pollution abatement costs over time, either creating these innovative technologies themselves or adopting cheaper pollution control technologies developed by other firms (Downing and White 1986).

This effect is strongest and most intuitive under a pollution tax. When reg-

5 Market power in the permit market (a small number of permit sellers) can lead permit sellers to withhold permits and drive up permit prices, establishing a correlation between initial permit allocation and the ability of the cap-and-trade system to achieve least-cost aggregate abatement (Hahn 1984). Marginal transactions costs that either increase or decrease with the size of permit trades may also establish such a correlation (Stavins 1995).

6 Moreover, the magnitude of the short-run cost advantage of taxes and permits over a uniform performance standard is directly correlated with the degree of abatement cost heterogeneity across regulated firms (Newell and Stavins 2003).

ulated by a unit tax on emissions, firms' compliance costs are the sum of abatement costs (for units of pollution they choose to reduce) and their tax bill (for units they continue to emit). A technology that reduces their marginal abatement costs will, thus, have two effects: (1) it reduces the abatement cost for each unit they chose to abate with the old technology; and (2) it reduces the firm's total tax bill – the firm will now abate additional units; for as long as the unit tax is unchanged, abatement now compares favorably with paying the tax over a greater range of abatement opportunities than it did before the cheaper technology was introduced. This extra savings associated with the reduced tax bill is absent under a performance standard. The incentive for long-run technological change under a tradable permit policy is also stronger than under a performance standard, but not as strong as under the tax (Milliman and Prince 1989, Malueg 1989, Jung et al. 1996).[7]

The fact that market approaches to pollution problems provide the strongest incentives to reduce the cost of solving those problems conflicts with the conventional wisdom. Outside of economics, belief in the power of the "technology-forcing standard" to promote innovation is strong. History suggests, however, that regulators are not very good at predicting how much improvement over existing technology is actually feasible for private firms, and by when, resulting in technology standards that are either unambitious, or too ambitious, and in any case remove dynamic incentives to develop new, better technologies (Jaffe and Stavins 1995).

2.2 Distributional Considerations

The discussion thus far has implicitly assumed that the damages from a unit of pollution are constant over space and time. This spatial and temporal "uniform mixing" of pollution is relevant to some environmental problems (e.g., greenhouse gas emissions), at least to a first approximation. However, many pollutants are non-uniformly mixed in the environment – hazardous waste may damage soil or groundwater at a specific site but have no effects outside a well-defined region. Between greenhouse gas emissions (almost perfectly uniformly mixed) and haz-

7 If permits are auctioned rather than distributed freely to polluting firms, this difference in long-run incentives for technological change between taxes and tradable permit systems disappears, since government revenues, rather than firm profits, absorb the impact of reduced permit prices (Milliman and Prince 1989).

ardous waste (highly non-uniformly mixed) lie a wide array of pollution problems for which non-uniform mixing is an important issue.

By construction, market-based approaches result in different quantities of abatement by different firms (low-abatement-cost firms reduce pollution more than high-cost firms). For non-uniformly mixed pollutants, MBIs that do not account for locational differences in the marginal damages from pollution may create pollution "hotspots", relative to CAC approaches that require equivalent reductions from all sources. This challenge has been carefully addressed in the environmental and resource economics literature. Establishing trading ratios that vary by each potential trading partner pair, in the manner of exchange rates, is a good approach (Oates et al. 1983, Tietenberg 2006, Hung and Shaw 2005, Farrow et al. 2005). Spatially- or temporally-differentiated taxes can also be designed in this context, and in some cases, "zoning" approaches, in which the value of abatement is weighted by geographic region, but not differentially for each firm, can be reasonable solutions (Boyd 2003).

3.0 A Bridge From Theory to Practice

Environmental economists' description over several decades of market-based policy instruments to deal with market failures represents a critical set of contributions that undergird the applications of market-based environmental policies in the United States, Europe and elsewhere. Several of these applications will be discussed further in Section 4. But academic economists have had many good ideas that have either gone unnoticed, or been expressly rejected by policymakers in legislatures and executive agencies. How is it that these particular good ideas in environmental economics – tradable permits in particular – have directly influenced environmental policy?

This is a story that has many potential starting points; Resources for the Future was established in Washington, DC in 1952, employing influential scholars such as John Krutilla and Alan Kneese during the 1960s and 1970s, and hundreds of others since then, bringing their research directly to consumers in the federal government (and to a smaller extent, states, and non-U.S. national governments). The field of environmental economics established its first flagship field journal in 1974, and the Association of Environmental and Resource Economists was established in 1979. The EPA added an Environmental Economics Advisory Committee to its Science Advisory Board in 1990 (Hahn et al. 2003).

But in the successful effort to put environmental economists' ideas into policy practice, it would be difficult to underestimate the role played by "Project 88: Harnessing Market Forces to Protect the Environment", a report prepared by Robert Stavins (1988), under the auspices of then-U.S. Senators Tim Wirth (D-CO) and John Heinz (R-PA). Project 88 laid out, in layman's terms, the strong arguments for using cap-and-trade and related market-based policy instruments to improve environmental quality. The report described concrete steps that could be taken to inject market forces and incentives into the management of climate change, local and regional air pollution, water pollution, water scarcity, public lands management, solid waste management, and other critical areas of environmental policy. The report was completed at the end of the Reagan Administration. According to former Senator Wirth, it heavily influenced the George W. Bush Administration's thinking on environmental policy, and on changes to the Clean Air Act, in particular (Eggers and O'Leary 2009).

The 1990 Clean Air Act Amendments established the sulfur dioxide (SO_2) trading program (discussed further in Section 4), known as the Acid Rain Program. SO_2 trading is but one fingerprint (albeit the most important one) of environmental economists' influence on the 1990 Amendments; EPA provided averaging, banking, and trading opportunities for most of the new standards promulgated under the Amendments, including those aimed at mobile sources.

Project 88 and its influence on environmental policymaking is proof not only that good economic ideas matter, but that they matter more when academics are motivated to take risks (relative to their own career incentives, which typically do not reward policy outreach), put those ideas in front of the people who make influential public and private decisions, and communicate them effectively. Though this conjecture cannot be empirically tested, it is reasonable to assume that the recent history of environmental policy in the United States and internationally would be very different without Stavins' persistent, clear, and carefully targeted policy outreach.

4.0 Successful Applications of Market-Based Approaches

The economic theory of environmental policy, and economists' successful efforts to promote them in policy spheres at the state, federal, and international levels, has affected the way in which governments regulate pollution. But it has also contributed to understanding several important natural resource depletion problems, including fisheries management and the conflicts between land development and preservation.

4.1 Using Markets to Reduce Air Pollution

In the 1980s, the EPA implemented a lead-trading policy to enforce a regulation reducing the allowable lead content of U.S. gasoline by 90 percent. The regulation was designed to reduce the negative externalities from air emissions of lead, including reductions in children's cognitive functioning and adult hypertension. Under the policy, refiners producing gasoline with a lower lead content than was required earned credits that could be traded and banked. In each year of the program, more than 60 percent of the lead added to gasoline was associated with traded lead credits (Hahn and Hester 1989). This policy successfully met its environmental goal, and the EPA estimated cost savings from the lead trading program of approximately $250 million per year until the phasedown was completed in 1987 (U.S. EPA 1985).

As discussed earlier, the U.S. has also used a market-based policy instrument – tradable emissions permits – to regulate emissions of SO_2, an air pollutant that damages human health and causes acid rain. The 1990 Clean Air Act Amendments required a 50 percent reduction in SO_2 emissions from older power plants, freely allocated the resulting permits to power plants, and allowed them to trade, creating an active market for SO_2 permits. While it operated, the U.S. SO_2 trading program produced cost savings of about $1.8 billion annually, compared with the most likely alternative policy considered during deliberations over the CAA Amendments, a technology standard (Keohane 2007). Early evidence of the policy's incentive for long-run, cost-reducing technological change is also positive; allowance trading seems to have boosted the incentive for utilities to adopt lower-cost technologies (Keohane 2007), and spurred firms that design and build scrubbers to raise removal efficiency (Popp 2003).

The Kyoto Protocol, the 1997 international climate change treaty ratified by 191 countries and the European Union, included emissions trading as a mechanism for achieving national emissions reduction targets. Among industrialized countries that took on emissions reduction targets under the Kyoto Protocol, the countries of the EU opted to use an emissions trading system, established in 2005, to meet their emissions reduction targets. The protocol sets a cap on CO_2 emissions for the EU as a whole, allocated by the EU to member countries.

Member countries then divide emissions allotments among major industries. The EU ETS is the world's largest emissions trading system, covering almost twelve thousand facilities in twenty-seven countries in 2014 (as well as intra-EU airline flights), and accounting for about 45 percent of EU CO_2 emissions (Ellerman and Buchner 2007, Convery and Redmond 2007).

The United States did not ratify the Kyoto Protocol, though the Obama Administration has set a national goal of reducing carbon emissions by 17 percent over 2005 levels by 2020 largely through prescriptive regulations. However, support for action on climate change has led some states to enact market-based policies to reduce greenhouse gas (GHG) emissions. California's Global Warming Solutions Act of 2006 (AB 32) will reduce GHG emissions to 1990 levels by 2020, with a cap-and-trade policy as its centerpiece. The program's first allowance auction took place in November 2012, and the cap began to bind in January 2013. The more stringent 2014 cap is scheduled to decline by 2.5 percent per year from 2015 to 2020.[8] By 2015, California's market will cover 85 percent of GHG emissions (from power plants, industrial sources, natural gas, and the transportation sector).

4.2 Individual Tradable Quotas for Fishing

Another common application of cap-and-trade policies is to fisheries management, to avert the tragedy of the commons. A market for fishing quotas works similarly to a market for pollution permits. The government establishes a total allowable catch (TAC), distributing shares to individual fishers, and fishers trade their assigned quotas.

The world's largest market for tradable individual fishing quotas (IFQs), created in 1986, is in New Zealand (Iudicello et al. 1999).[9] By 2004, it included seventy different fish species, and the government of New Zealand had divided coastal waters into "species-regions," generating 275 separate markets that covered more than 85 percent of the commercial catch in the area extending two hundred miles from New Zealand's coast. In the United States, Pacific halibut and sablefish off the coast of Alaska, mid-Atlantic surf clams and ocean quahogs, South Atlan-

8 Another U.S. market-based initiative is the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade system among electricity generators in nine northeastern states. See Murray et al. (2014).

9 For an assessment of New Zealand's policy, see Newell et al. (2005).

tic wreckfish, and Gulf of Mexico red snapper are all regulated using IFQ markets. Iceland manages stocks of twenty fish and shellfish species using IFQ markets, in a system established in 1990. An analysis of catch statistics from 11,315 global fisheries between 1950 and 2003 provides the first large-scale empirical evidence for the effectiveness of these approaches in halting, and even reversing, the global trend toward fisheries collapse (Costello et al. 2008).

4.3 Water Quality Trading

Following their successful application to several air quality problems, expectations have been high for the successful transfer of tradable permit policies to water quality regulation. EPA estimates that expanded use of water quality trading in the United States could reduce total compliance costs associated with total maximum daily load (TMDL) regulations under the Clean Water Act by $1 billion or more annually (U.S. Environmental Protection Agency 2001). Active water quality trading programs include: (1) the salinity trading program in Australia's Hunter River; (2) Connecticut's Long Island Sound Nitrogen Credit Exchange; (3) the Minnesota River phosphorus trading program; and (4) state-level trading in Pennsylvania, Virginia and Maryland of nutrients flowing to the Chesapeake Bay (Fisher-Vanden and Olmstead 2013). Total cost savings relative to a uniform performance standard for the Long Island nitrogen trading program from 2002-2009 may have been as high as $300-400 million (Connecticut DEP 2010). Potential cost savings from the Chesapeake Bay trading programs are $78 million per year if point sources are allowed to trade only with other point sources, within a river basin, and within a state—a 20 percent decrease relative to no trading; potential savings escalate with broader markets (Van Houtven et al., 2012).

The active water quality trading programs developed thus far, however, are significantly thinner than what might be optimal from an economic perspective (Fisher-Vanden and Olmstead 2013). The main reasons for this have to do with challenges regarding the physical characteristics of water pollution problems, and challenges posed by the implied rights to pollute created by the current regulatory environment. In terms of the physical characteristics of water pollution, damages from water pollution often vary significantly with the location of the discharge. This spatial heterogeneity requires policies to include spatial trading ratios, zones, or other mechanisms to ensure that environmental goals are met, as discussed in Section 2.3. This problem complicates the establishment of water quality trading programs in practice. In terms of the regulatory environment, in industrialized countries, the exclusion of major low-abatement-cost agricultural sources from direct water quality regulation has hampered the establishment and success of water quality trading. In most such countries, nonpoint source (NPS) pollution is the most significant remaining major source of water quality impairment.[10] Nonpoint source pollution involving nutrients like nitrogen and phosphorus causes excessive aquatic vegetation and algae growth and eventual decomposition, which deprives deeper waters of oxygen, creating hypoxic or "dead" zones, fish kills, and other damages. Though agricultural facilities are the most significant source of these pollutants in many watersheds, they are not directly regulated.

4.4 Waste Management Policies

Market-based approaches have also been used to manage household solid waste. The marginal cost of public garbage collection and disposal for an American household has been estimated at $1.03 per trash bag, but until recently, the marginal cost of disposal borne by households was approximately zero (Repetto et al. 1992). But an increasingly common waste management policy, known as "pay-as-you-throw," assesses a unit waste disposal charge in the form of a requirement for the purchase of official garbage bags, stickers to attach to bags of specified volume, periodic disposal charges for official city trash cans of particular sizes, or (rarely) charges based on the measured weight of curbside trash. In 2006, more than seven thousand U.S. communities had some form of pay-as-you-throw disposal (Skumatz 2006). Studies suggest that these environmental charges do reduce the volume of waste, though illegal disposal may also increase (Fullerton and Kinnaman 1996, Huang et al. 2011).

4.5 Habitat and Land Management Policies

Tradable development rights (TDRs) have been applied to solve problems as diverse as deforestation in the Brazilian Amazon and the development of former farmland in the Maryland suburbs of Washington, DC. TDRs allow conversion

10 Common nonpoint sources of water pollution include agricultural and urban runoff, atmospheric deposition, and runoff from forests and mines, all of which enter water bodies over diffuse areas. NPS pollution from agricultural activities is the primary source of impairment in U.S. rivers and streams (U.S. Environmental Protection Agency 2009).

of land from environmentally or aesthetically beneficial uses (e.g., forest or farmland), with preservation elsewhere guaranteed in exchange. About 140 U.S. communities have implemented TDRs. The program in Calvert County, Maryland, preserved an estimated thirteen thousand acres of farmland between 1978 and 2005 (McConnell et al. 2006). In Brazil since 1998, TDRs have been used to slow the conversion of ecologically valuable lands to agriculture (Chomitz 2004). A related policy, wetlands mitigation banking, requires land developers to compensate for any lost wetlands by preserving, expanding, or creating wetlands elsewhere (National Research Council 2001). Wetlands banks serve as central brokers, allowing developers to purchase credits, and fulfilling credits through the physical process of wetlands preservation, creation, and management. In 2005, there were 405 approved U.S. wetland banks in operation.

Landowners under each of these policies can develop the most profitable land and preserve less profitable land. But this highlights two problems. First, how can land developers prove (and regulators ensure) that a preserved parcel is really additional—that it would not have remained in forest or another protected use without the developer's efforts? Second, how can we measure the ecological or other equivalence of two land parcels? For example, coastal wetlands support shellfish nurseries and may reduce damages from storm-related flooding. Inland wetlands may filter contaminants and provide islands of habitat for migratory bird species in overland flight. If development pressures in coastal cities create incentives for landowners to develop wetlands in these locations, and pay for wetlands creation inland, the net effect of these kinds of trades must be considered.

5.0 Future Challenges for Market-Based Environmental Policy Instruments

One significant future challenge for the expansion of market-based environmental policy instruments is their relative rarity. The existing body of environmental regulation, even in the United States, which has applied market-based policy instruments more expansively than most countries, is achieved overwhelmingly with prescriptive policy instruments. This is true at the federal level (Hahn et al. 2003), and even more so at the state level. For example, environmental, health and safety regulation of the oil and gas industry is accomplished primarily by state regulatory agencies. In 2013, research suggested that 81 percent of regulations addressing environmental risks from shale gas development in 27 states were prescriptive -- overwhelmingly technology standards, with a handful of examples in four states of somewhat more flexible performance standards (Olmstead and Richardson 2014).[11] Thus, shifting the existing regulatory apparatus so that market-based approaches predominate would be like turning the proverbial battleship. In addition, experience with market-based policy instruments among both regulators and those responsible for regulatory compliance in the regulated community (who tend to have legal backgrounds, rather than training in economics) is thin, so efforts to inject market incentives into new environmental regulations may still be confronted with skepticism and resistance.

A second challenge has to do with the physical complexity of many of the environmental policy problems still regulated using prescriptive approaches. In particular, when the marginal damages from pollution and other activities vary spatially, if high-damage sources also have low abatement costs, trading can cause net welfare losses; any cost savings relative to a CAC policy may be more than counterbalanced by reduced benefits. In Section 4.3, we noted that non-uniform mixing of water pollutants has been a barrier to the establishment and success of some water quality trading programs. Similarly, the transport of SO_2 air pollution from power plants in the Midwest to East Coast states played a decisive role in recent litigation and regulatory action that dismantled the U.S. SO_2 trading program.[12] Going one step further, the slow adoption of market-based policy instruments to address local land management issues, such as forest and wetlands conversion, is strongly linked to the non-uniform mixing problem in air and water pollution regulation. Trading parcels of land on a one-to-one basis when the impacts of development conversion may vary dramatically (and uncertainly) over space is not likely to be efficient, let alone cost-effective.

Thus, while existing applications of MBIs have not been easy to accomplish politically or in practice, they may represent the "low hanging fruit" of regulatory problems amenable to MBIs. On the positive side, academic research on the efficiency and feasibility of MBIs that deal with spatial damage heterogeneity is growing (Farrow et al. 2005, Muller and Mendelsohn 2009, Fowlie and Muller 2013).

11 The remaining 19 percent of state oil and gas regulations affecting environmental risks from shale gas development were not market-based, per se, but were examples of "case-by-case" permitting. This is flexible, but…(Richardson et al. 2013).

12 It remains to be seen whether this can be resolved under the current Clean Air Act, or whether Congress will consider changes that allow more scope for market-based approaches to regional air quality regulation.

We may be on the cusp of pushing out the frontier of market-based environmental policy applications even further, should these academic results be successfully communicated to policymakers. Note, however, that while market-based policies can be designed for spatially heterogeneous damages, they are not workable in extreme cases. Environmental problems that are highly non-uniformly mixed may be better addressed through prescriptive approaches.

Third, market incentives in environmental regulation face direct and indirect political challenges. In terms of indirect challenges, legislators may exclude key (high emissions and/or low abatement cost) industries from cap-and-trade or tax policies due to those industries' political influence, dramatically reducing both effectiveness and cost-effectiveness of market-based regulations – essentially "setting them up to fail". A good example is the exclusion of agricultural facilities from most Clean Water Act regulations, so that they either do not participate in water quality trading programs under that statute (limiting achievable pollution reductions, and increasing costs), or are coaxed to participate through subsidies and other costly means (Fisher-Vanden and Olmstead 2013). Another example is the exclusion of industries such as cement and metals production from Norway's CO_2 tax, established in 1991 (Bruvoll and Larsen 2004). Other indirect political challenges may come about through policymakers' lack of faith in market-based approaches, causing them to design policies that hamper markets' functioning. A recent example is the set of policy instruments designed to reduce California's CO_2 emissions, which do include a cap-and-trade program, but also other policies that work to its detriment (Schatzki and Stavins 2013, Borenstein et al. 2014). Critics of MBIs may gain traction in their opposition by pinning any resulting failures on the choice of policy instrument, rather than poor regulatory design.

Of course, direct political challenges exist, as well, especially given the divisiveness of environmental policy issues. The recent efforts by conservatives in the U.S. Congress to label cap-and-trade as "cap-and-tax", and otherwise demonize market-based environmental policies, along with environmental regulation altogether, are one example (Stavins and Schmalensee 2013). Using markets to correct environmental market failures was a conservative idea in the 1980s and 1990s, supported by Republican administrations and moderate environmental organizations well before it gained broader support. As the political ground has shifted rightward under these policies' feet, it may be much more difficult, at least temporarily, to achieve sensible market-based reform of environmental policy.

6.0 Conclusion

This paper has summarized the principles of market-based environmental policy developed by economists over the past several decades, discussed how those academic principles have been translated into applications from air and water pollution control to fisheries and land management, and identified three important challenges to expanding the influence of market incentives in environmental policy. The key role of Robert Stavins in both developing market-based environmental policy principles in his academic work, and translating those principles into policy applications through outreach and public service, has been emphasized.

The remaining challenges to increasing the influence of markets in environmental regulation are significant. MBIs play a role in a tiny fraction of all U.S. environmental regulation at the state and federal level; changing this requires a broad paradigm shift in regulatory policy. Many environmental problems have complex spatial patterns, so that a new generation of market-based instruments must take into account spatial variation in a policy's benefits, while exploiting spatial heterogeneity in compliance costs. Recent research suggests that academic economics has a lot to offer in overcoming this challenge. Market-based policy instruments in practice often look very different than those described in theory, with key (politically powerful) sectors excluded, and market-hampering additional policy approaches added as "insurance." The resulting policies may offer poor examples of what market-based approaches can achieve, making future applications more difficult. Finally, direct political challenges to market-based environmental policy instruments are significant when environmental policy, itself, is a divisive issue. Effective responses to each of these challenges will require both robust economic research contributions, and effective communication of these contributions to the public and private decision makers who shape the environmental policy agenda.

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Linking Sound Economics with Global Politics

Gernot Wagner[1]

Stabilizing the world's climate entails a massive, global policy push. That, in turn, implies coordination at an unprecedented scale. Progress on such a coordinated, global, 'top-down' solution has been slow, to put it mildly. It's no wonder then that emphasis has shifted toward a more 'bottom-up' solution. Policies, after all, are enacted at the national, regional, or local level. And each country or jurisdiction needs to find its own, ideal policies *before* then linking up with others.

There's a lot to that logic. In particular, basic economics shows how linking of domestic emissions trading systems can only be good: it allows for more ambitious climate action at lower cost than separate domestic policies.[2] That reasoning is sound. However, it does not absolve us of thinking hard about the political dynamics that have made a global climate deal so difficult. The need for coordination does not go away in a bottom-up approach to climate policy. It merely moves to a different plane.

We'll first discuss the fundamental economic argument for linkage before diving into the politics.

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2 See, for example, Burtraw et al., 2013; Green, Sterner & Wagner, 2014; Jaffe, Ranson & Stavins, 2010; Jaffe & Stavins, 2008; Metcalf and Weisbach, 2012; Ranson & Stavins, 2012; Stewart et al., 2013.

1. The Economic Case for Linking

The economics of linking are sound: the bigger the market, the larger the potential benefits. Marginal costs of abatement vary within and across countries. So do levels of ambition. The greater is the sum of the differences, the larger the potential gains from trade.

To formalize the standard economic argument for linkage, consider two countries, one developed and one developing. Assume the developed country faces a high marginal abatement cost curve, MC_H, whereas the developing country's curve is much lower, MC_L.

Assume that the developed country faces a high initial emissions reduction target, X_H^0, whereas the developing country faces a lower target of X_L^0. Total abatement across both countries will equal $\Sigma X^0 = X_H^0 + X_L^0$ (Figure 1).

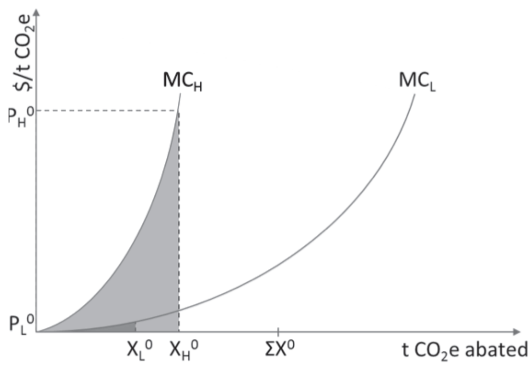

Figure 1*:* Initial allocation of abatement commitments and costs for high and low-abatement cost countries.

Figure 1 shows a world without trading, where the large shaded area under MC_H represents the total cost of emissions abatement for a given level of emissions reduction in the developed country, and the small shaded area under MC_L represents the total abatement cost in the developing country.

The developed country faces significantly higher costs than the developing country. In particular,

$$P_H^0 >> P_L^0,$$

and, thus, given $X_H^0 > X_L^0$ assumed above,

$$\int_0^{X_{H^0}} MC_H \gg \int_0^{X_{L^0}} MC_L.$$

Linkage across the two countries, then, could potentially decrease overall costs significantly while keeping the initial abatement target intact (Figure 2).

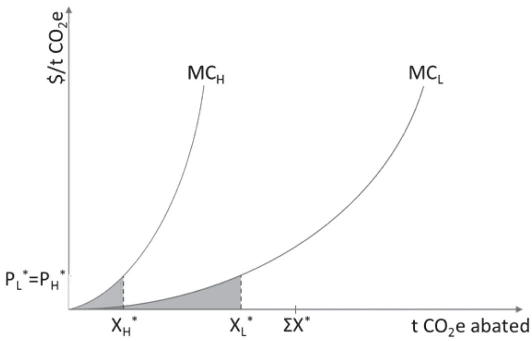

Figure 2: Efficient allocation of abatement commitments with trading.

Overall abatement across both countries, ΣX^*, equals the initial position from Figure 1, ΣX^0, yet total costs are much lower. Trading allows for the same level of emissions reduction at lower cost, as represented by the significantly smaller combined shaded areas in Figure 2. (Alternatively, much more abatement could have been achieved for the same total cost, if only most of the money were spent in the developing country, with lower abatement costs.)

Figure 3 takes the precise areas from Figure 1 and Figure 2 and shows their relationship more directly. The top line comes from Figure 1, showing the initial abatement commitment and costs. The bottom comes from Figure 2, showing the final abatement commitments and costs for the developed and developing country, respectively.

Total abatement remains the same,

$$X_H^{\ 0} + X_L^{\ 0} = X_H^{\ *} + X_L^{\ *},$$

but there are potentially large gains from trade:

$$\int_0^{X_{H^0}} MC_H + \int_0^{X_{L^0}} MC_L \gg \int_0^{X_{H^*}} MC_H + \int_0^{X_{L^*}} MC_L.$$

The total abatement costs without trading are much larger than the total costs with trading, despite equal overall abatement efforts across both regions.

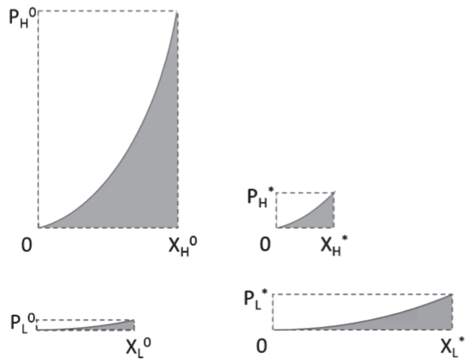

Figure 3: Abatement and costs by high and low-cost countries (top and bottom, respectively), before and after trading (left and right), taking the precise areas from Figures 1 and 2.

While overall abatement cost declines under trade, it is important to note that linking across jurisdictions will create winners and losers both within and across cap-and-trade systems. Within a particular cap-and-trade system, net buyers will stand to gain if the post-linkage market price is lower than prior to linkage. Similarly, net sellers will stand to gain if the post-linkage market price is higher. This creates natural constituents for linkage as well as natural opponents within any cap-and-trade system.

Linkage also generates winners and losers across cap-and-trade systems. In economic terms, this implies a *potential* Pareto improvement from trading. While total abatement costs across both countries are significantly smaller after trading, costs to the developing country will rise.

To turn this potential Pareto improvement into an actual one requires monetary transfers from the regulated entities in the developed country to those in the developing one. These financial flows must be greater than the additional cost to the developing country, yet smaller than the cost savings from the developed country:

$$\int_0^{X_{L^*}} MC_L - \int_0^{X_{L^0}} MC_L \leq transfers\ across\ regulated\ entities \leq \int_0^{X_{H^0}} MC_H - \int_0^{X_{H^*}} MC_H\ .$$

These financial flows are potentially large and could lead to significant overall cost savings, amounting to half of overall abatement costs (Dellink *et al.* 2010).

Domestic political objections to transferring wealth abroad could prevent some jurisdictions from linking, or they could lead jurisdictions to weaken their domestic policies in the first place.

This point is worth emphasizing. It is generally assumed that the low-income country has the opportunity to 'save' on overall costs by abating more. But the incentives for doing so depend on money going from covered entities in high-income nations to those in developing ones. Financial flows—both within the private sector and among governments—are also at the heart of the politics. It is not surprising that the developing world advocates for much bigger overall transfers than the developed world, a fundamental difference in negotiating positions that has made a global grand bargain extremely difficult.

2. Economics Meets Politics

As long as there are differential marginal abatement costs across nations, linked markets can be both economically more efficient and environmentally more effective than separate systems. It's hard to find fault with the economic logic that linked jurisdictions can jointly achieve greater reductions at lower cost.

Insights from both political science and economic practice, however, suggest reasons to be more cautious. The assumptions of our simple model ignore important political dynamics, which, if not addressed, could ultimately undermine the promised benefits of linked domestic carbon markets. These problems are especially likely among jurisdictions with wildly different marginal abatement costs, where environmental and economic gains from linkage could, in theory, be largest. In particular, linkage will encounter four potential obstacles that need to be considered.

First, success requires that participating jurisdictions do not game the system by setting unambitious caps in order to maximize short-term, domestic economic gain at the cost of overall environmental effectiveness. Second, successful linkage needs to be compatible with other domestic policy objectives. Third, it requires political support for potentially large financial flows across jurisdictions. Fourth, any successful market linkage demands close regulatory coordination, which becomes increasingly difficult as more jurisdictions—in particular those with unequal marginal abatement cost curves and differential regulatory capacity—join a linked market system.

2.1. Different Levels of Ambition

Flexibility can be both the impetus for and the downfall of linkage. A stringent domestic target makes linkage more attractive because it allows for purchasing cheaper allowances from abroad. However, the same logic applies to setting the domestic climate target in the first place. Each country has an incentive to set an unambitious target, and gain from selling cheap credits to the wider market. If targets were set in stone, that would not be too great a problem But, of course, they aren't. Domestic climate targets are the result of intense internal political negotiations. The possibility of linking then adds another complicating factor.

A pure bottom-up approach, in short, may afford *too much* flexibility in one of two ways. First, each jurisdiction could simply choose an unambitious cap in the first place. Second, a given jurisdiction could lower its level of ambition if compliance becomes too costly.

For a real-life example of the problems an unambitious cap can create in a cap-and-trade system, look no further than the trial phase of the EU Emissions Trading System (ETS). From 2005 to 2007, individual member states were able to set their own emissions reduction targets (Ellerman, Convery & De Perthuis, 2010). The individual country-level caps were then added together to get to the system-wide cap. Unsurprisingly, countries set caps above what they actually needed, in order to minimize the short-term costs of cap and trade on their industries. The result: over-allocation of allowances in Phase I, and a significant drop in prices in April 2006, once that over-allocation became evident to market participants.

Importantly, while allowance prices for Phase I decreased significantly (eventually approaching zero, because Phase I allowances could not be used in future periods), futures prices for Phase II allowances held comparatively stable. In Phase II, the ETS became closer to a top-down arrangement. Though based on earlier domestic allocations, Phase II allocations no longer allowed member states to set their own caps. Instead, the European Commission was given the authority to change member state's proposed caps. The allocation mechanism resembled something much closer to a top-down 'targets and timetable' approach.

A further problem is that too much flexibility after two systems link can lead jurisdictions to lower their previously stated levels of ambition. If allowances become sufficiently scarce, then linked jurisdictions can raise caps or increase the availability of credits from other markets. In the former, the trading entity essentially prints money by creating more allowances (Victor and House 2004).[3] In the latter, regulated entities can seek offset credits in other markets—presumably with lower prices—allowing them to meet reduction requirements without much change in their own level of emissions.

Enhancing supply through either raising caps or opening markets to offset credits has two effects. First, and most obviously, it reduces the level of ambition of climate change policy. A higher cap means less abatement. Lowering levels of ambition domestically is also likely to spark a race to the bottom in linked systems. Raising caps within a given cap-and-trade market means reducing its marginal cost of abatement; thus, that market has less to gain from purchasing credits from other linked markets. As marginal costs of abatement equalize across markets, gains from trade among linked jurisdictions approach zero. Jurisdictions that choose not to raise their caps will face higher costs. In turn, this may spark a race to the bottom. In this sense, the 'bottom-up' approach quickly creates interdependencies among linked markets where collective action is needed to avoid beggar-thy-neighbor policies—precisely the dynamic that has plagued the international process.

This 'race to the bottom' is most likely to occur among trading jurisdictions with widely different marginal abatement cost curves. Two developed-world jurisdictions with similar levels of ambition, marginal abatement costs and overall system designs may find it relatively easy to overcome this obstacle. However, there is little economic gain in terms of lower overall abatement costs from such a link. Instead, the economic advantages come from having a larger overall market and, thus, increasing the fungibility of allowances. This logic, for example, applies to the link between California and Quebec, where the dynamics described here are largely absent. They become more pronounced as the wealth gap between countries widens.

2.2 Competing Domestic Objectives

The logic for linkage relies on the simple assumption that each jurisdiction wants to reduce overall, short-term compliance costs. It's not difficult to believe

3 This can, of course, go either way; states could also decide to *lower* caps, making environmental targets more ambitious. The Regional Greenhouse Gas Initiative recently took such a step, announcing plans to tighten its caps by 45%. The EU is considering similar steps around "backloading" allowances and, thus, temporarily tightening its own cap.

that this assumption usually holds. Yet, linkage will produce winners and losers within (and across) given jurisdictions; not everyone will necessarily benefit from lower compliance costs. In a jurisdiction with higher costs relative to its linked counterparts, those with high marginal costs of abatement will be pleased by the lower permit costs after linkage. However, potential permit sellers—that is, those with low costs of abatement—will lose out, since they may be undercut by cheaper allowances purchased abroad. Thus, although overall costs would be reduced by linkage, within each country, these costs will be unequally distributed.

Then there is a potentially even more fundamental problem. Some, like the EU, are clearly not acting from a desire to minimize short-term economic costs. In fact, the very act of being a first-mover on climate change like the EU implies shouldering higher costs now for greater benefits later. As a result, some countries may be skeptical about linkage simply because they want to maintain a relatively high domestic carbon price in the short run. Jaeger *et al.* (2011), for example, shows an inherent time tradeoff: steeper emissions targets now may result in cheaper abatement costs in the future. Following this line of thought, lower short-term prices achieved through linkage may not be in the strategic interest of all. Countries that wish to spur innovation or that have strong renewable energy sectors may not wish to lower the price of carbon in the short-term.

That said, linkage is, in fact, part of the EU's overall climate policy plan toward "global cooperation on climate change."[4] The EU then serves both as an example for why the simple economic logic for linkage may well be too simple, and why political reasoning is just as crucial. The politics sometimes undermines the simple economic logic and at other times reinforces the drive toward linkage. In the final analysis, even politically motivated linkage will face issues of lower levels of ambition as well as the subsequent two barriers: the need for financial flows, and the potential loss of regulatory autonomy.

2.3 Need for Supporting Financial Flows

The economic logic of linkage rests on differential marginal costs of abatement and the resulting international monetary transfers (section 1). As soon as it is cheaper to abate in one country over another, permits are bought and sold on the international market. This activity is akin to a financial transfer between

4 *International Carbon Market* (2014).

trading entities.

Large scale financial flows of capital—especially from developed to developing countries—of course, are likely to face the same obstacles as those that occur through a top-down agreement. The negotiations around mobilizing $100 billion per year from developed to developing countries by 2020 for mitigation and adaptation, from both public and private sources, provides one example of the difficulties embedded in such a negotiating process. Only a fraction of the $100 billion has been committed from public sources, and even less of that has been disbursed.[5] Setting up one of the funding vehicles, the Green Climate Fund, has been an extremely contentious process (Abbott and Gartner 2011).

In essence, full linkage among a broad swath of developed and developing countries and jurisdictions will effectuate the very same types of financial flows that have been controversial in the Copenhagen Accord and also, for example, the Clean Development Mechanism. Assuming similar levels of ambition, the size of the eventual transfers in bottom-up situations will likely be similar to those required for a top-down deal.

2.4 Loss of Regulatory Autonomy

Lastly, linking markets also implies linking governing mechanisms. Governments need to agree on what to do and how to do it. That goes for seemingly mundane design questions and for much more fundamental questions: Will links be one-way or two-way? Will they include offset credits or allowances? Will full banking and borrowing be permitted? Will there be limits on the number of allowances or credits permissible from other markets? Since design choices in one jurisdiction will affect policy in another, these decisions could be contentious, to say the least. They clearly lead to loss of regulator autonomy.

Two key regulatory challenges emerge. First, linkage requires robust regulatory frameworks. Carbon markets create a unique commodity. The metric ton of CO_2e is entirely a policy creation which requires careful and sustained oversight. Measurement, monitoring, reporting, verification, compliance, and enforcement issues are paramount. Linking jurisdictions need to agree on standards as well as on controls for quality and quantity of third-party offset credits. Jurisdictions

5 See the UNFCCC Finance Portal for Climate Change for the most updated figures: http://www3.unfccc.int/pls/apex/f?p=116:8:5075510030800287. See also: Buchner *et al.* (2012).

with lax compliance will likely see the price of their allowances drop, and environmental effectiveness decline.

A second challenge that compromises regulatory autonomy is the increased interdependence among linked jurisdictions. Larger trading systems achieved through linkage would increase liquidity. However, they will also propagate any possible early mistakes in system design. At the extreme, the collapse of one system—either because of design flaws, regulatory uncertainties, or other economic or political circumstances—could have serious impacts on linked markets.

Threats to regulatory autonomy will prompt linking jurisdictions to negotiate for favorable designs. Some linking jurisdictions will push to lock-in favorable rules; others may want flexible rules that can be amended to ensure favorable circumstances in the future. Late-comers may lobby for changes in the rules, or be dissuaded from joining altogether.

The appeal of bottom-up markets is, in some way, to experiment with and see the effects of different ETS designs. Linking markets may prematurely lock in these designs and set *de facto* standards across large, international trading systems. One fear is that early linkage of markets will lock in design standards that have yet to withstand the test of time or, worse, create a race to the bottom when it comes to setting overall regulatory standards.

3. A Path Forward: An Incremental Approach to Linkage

The 'top-down', Kyoto-style approach to setting targets and timetables failed largely because countries couldn't agree on how much to do and how much to spend. The 'bottom-up' approach of letting countries set their own levels of commitments would seem at first glance to avoid much of those problems. However, such an approach still clearly needs strong coordination, and can run into issues of its own.

As states develop their national climate policies, we will see a combination of bottom-up arrangements and top-down negotiations. As different domestic systems try to link, they will confront issues related to the level of ambition, oversight and policy design. Some of these coordinating challenges may be easier than others. The setting of the overall cap in each jurisdiction, for example, is likely the most visible process, which will raise different questions from other less visible design decisions such as the verification of third-party offsets.

This bottom-up process may create a renewed interest in and impetus for more globalized agreements. International climate architecture could do worse than mimic the EU's 'model.' Right now, we are in the global equivalent of something akin to the EU's Phase I, where each country sets its own level of ambition. The Durban Accord and mandate to negotiate a global set of ambitions by 2015, to become effective by 2020, already points the way toward Phase II, where there is some loose coordination of caps. Most importantly, everyone from climate negotiators to domestic politicians designing their own domestic systems, should keep the global equivalent to EU-ETS's Phase III in mind—a hierarchical system with a firm, global cap on emissions.

Until then, linkage ought to be taken for what it is: a potentially important but also limited step toward a more globalized climate policy. Early linkages reveal the political if not the economic advantages of such arrangements. That said, bottom-up systems will not be able to avoid the very real issues that have haunted top-down negotiations for so long. The larger the economic advantages to linkage, the greater will be the visibility of issues such as overall levels of ambition, supporting financial flows, regulatory autonomy, and competing domestic objectives.

We are in the experimental phase of a potentially far-reaching undertaking: creating a global market for carbon. Given the complexity of this project, it is only prudent to proceed with caution. The simpler are the linkage arrangements, the better. One way forward may well be to place limits on early linkages, in order to minimize potential risks, while still learning from the process. By only allowing a certain amount of allowances to flow between linked markets, or by starting slow, with short-term linkages, jurisdictions can protect themselves from potential negative consequences. Markets engaged in linkage should first focus on creating sound infrastructure for global carbon markets, a process that begins at home.

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Carbon Pricing: From Theory to Reality

Yoram Bauman PhD[1]

The theory behind carbon pricing goes back to Pigou's 1920 book, *The Economics of Welfare*, which first made the case for using environmental taxes to internalize externalities.

In the nearly 100 years since Pigou's book, his prescription has been widely endorsed by economists and just as widely ignored by policymakers. There have been a few successes—the SO_2 trading program in the 1990 Clean Air Act Amendments, the British Columbia carbon tax, greenhouse gas trading programs in Europe (the EU Emissions Trading System), in a collection of East Coast states (RGGI), and in California (AB32)—but by and large climate policy has either been avoided entirely or handled through traditional regulations.

It is a credit to Robert Stavins that there have been any successes at all. He has played a pivotal role in many of the existing policies, including as Director in the late 1980s of Project 88 (Stavins 1988), a report that catalyzed the SO_2 trading program. More recently, Stavins has studied a variety of climate policies through his work with the Harvard Project on Climate Agreements, and the IPCC.

In this paper, I aim to complement Stavins's work by providing more of a bottom-up perspective, one that is perhaps more akin to the view that Stavins himself may have had as a newly minted PhD in 1988. (I hasten to add that in 1988 Stavins was already an assistant professor at Harvard working with national leaders, so my "bottom-up perspective" is from a much lower bottom!) As befits a bottom-up perspective, my focus in this paper will be quite narrow: on carbon pricing efforts on the west coast of North America in general and in Washington State in particular.

Before pursuing that focus, however, a bit of perspective is in order.

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1. Think Globally, Act Locally

To grasp the international challenge, consider what I call the "5 Chinas" theory of the world (Bauman 2014a), which divides the world population of about 7 billion people into 5 China-sized chunks that each have about 1.4 billion people:

- China
- India
- Other developing Asia: Indonesia, Bangladesh, Pakistan, Vietnam, the Philippines, etc.
- The rich world: North America, Europe, Japan, South Korea, etc.
- Everyone else: Principally Africa and South America.

At the beginning of this century the rich world—just one of these "5 Chinas"— accounted for about half of world CO_2 emissions (IEA 2010). A simplistic but illustrative projection would feature "catch up" from the other 4 Chinas by 2100, plus the addition of at least two more China's worth of people to the planet. (Current UN projections [UN 2012] show a peak of 10-11 billion towards the turn of the next century.) If each of these Chinas produces as much CO_2 as the rich world currently produces, world CO_2 emissions would increase by 250% over the course of this century. (If rich world CO_2 emissions are x, emissions will rise from $2x$ to $7x$.) As an illustrative example, China passed the U.S.A. as the top carbon emitter in the world in 2006 and is likely to reach roughly double U.S. emissions by 2016, but even at double U.S. emissions China's emissions per capita will be about half of the level in the U.S.A. because China has about four times more people than the USA.

What then is the point of local climate policies? Opponents of local climate action in Washington State often emphasize that the state accounts for about one-third of one percent of global CO_2 emissions, but of course, the point of action in Washington State is not to "solve" climate change in Washington State, but to influence action at larger scales. In particular, state-level action can serve as a "laboratory of democracy" to influence national action. (A reasonable model, for better or worse, is how the Massachusetts health care law, aka Romneycare, influenced the Affordable Care Act, aka Obamacare.)

State-level action is especially important at the moment given the poor political prospects for climate action in the U.S. Congress; hopefully, state-level action can inspire national action. And hopefully, national action can inspire international action, perhaps through an international agreement on carbon taxes or an international cap-and-trade system. Given the growing importance of China, India, Africa, and the rest of the developing world, international action will be necessary to stop the growth of world carbon emissions. (I will note, however, that international action may not require an international agreement. Indeed, the easiest "solution" that I can see is for the U.S.A. and other rich countries to use carbon pricing and/or government research funds to pursue clean-energy research and development (R&D); if that R&D miraculously leads to the development of clean energy options that are cheaper than fossil fuels, the rest of the world will adopt them simply because they are cheap, without the need for any sort of global treaty.)

The remainder of this paper will therefore focus on the west coast of North America, and in particular on Washington State, as a case study for progress on carbon pricing. In addition, I believe that there is a decent chance that what happens in this region will drive national and international climate policy in the years ahead. That is because Washington (like Oregon, which could play a similar role) is sandwiched between two jurisdictions that represent two paths forward on carbon pricing: British Columbia, which has a carbon tax, and California, which has a cap-and-trade system.

2. West Coast Background: British Columbia's Carbon Tax, California's Cap-and-Trade

In February 2008, the government in British Columbia (BC) adopted what many economists consider to be the best climate policy in the world. There are many oddities about the BC carbon tax, not least of which is that the policy closely approximates what might appear in an economics textbook.

Another oddity is that the policy was passed by a right-of-center government, the confusingly named Liberal Party. (The reference is to classic or European-style liberalism, or what in the U.S.A. we would call libertarianism.) According to the conversations and readings (Durning 2008) I've been privy to, the driving force was Premier Gordon Campbell, who personally pushed the carbon tax into existence despite opposition or ambivalence from just about everybody in BC except for economists (Green 2007). Indeed, at the election that came a year after the carbon tax was introduced, the left-of-center New Democratic Party campaigned *against* the carbon tax, arguing that it was unfair. (This prompted some environmental groups to endorse the Liberal Party, which won re-election; in the end, the carbon tax probably ended up playing a relatively small role in tilting the election in either direction [Lorinc 2009].)

The BC carbon tax (see Durning and Bauman 2014) applies to almost all fossil fuels burned in the province of British Columbia. ("Process emissions" from industries such as aluminum and cement manufacturing are excluded, as are fuels loaded onto planes and ships heading beyond the province's borders; the carbon tax also does not apply to "carbon by wire", i.e., the carbon content of imported electricity.) The tax started at $10 per ton CO_2 in July 2008 and increased by $5 per ton per year through July 2012, when it plateaued at $30 per ton. (All figures for the BC carbon tax are in Canadian dollars and in metric tonnes, which fortunately are nearly at parity with American dollars and short tons, respectively, but note that throughout this paper "tons" means "metric tons".) For context, $30 per ton CO_2 is approximately $0.30 per gallon of gasoline, $0.03 per kilowatt-hour of coal-fired power, and half that for natural gas.

In short, the BC carbon tax can be summed up with a haiku:

Fossil CO_2
Thirty dollars for each ton
Revenue neutral

If British Columbia is a haiku, California is *War and Peace*. That's not necessarily bad—*War and Peace* is considered one of the greatest novels ever written—but it makes it difficult to provide a concise overview. I'm going to try anyway.

California's Global Warming Solutions Act of 2006, often referred to as AB32, includes a host of provisions that aim to return the state to 1990 emissions levels by 2020. What happens after 2020 depends on whether and how the state government extends the program, e.g., to enforce a (currently non-binding) executive order to reduce emissions to 80 percent below 1990 levels by 2050.

Although attention often focuses on the cap-and-trade component of AB32, this focus may be unwarranted. According to the Electric Power Research Institute (EPRI 2013), the latest estimate from the California Air Resources Board (ARB) suggests that *80 percent* of the promised emissions reductions will come from "complementary policies" such as a Low Carbon Fuel Standard, Advanced Clean Car standards, and a Renewable Portfolio Standard. The cap-and-trade program "cleans up the rest." Economists tend to dislike this type of complementarity—the underlying philosophy of cap-and-trade is for the market to identify low-cost carbon-reduction activities, not the government, and Robert Stavins (2009) has been a prominent critic of California-style complementarity—but we'll leave for another time a broader discussion of market failure versus government failure.

Having noted that a focus on cap-and-trade may not be warranted, I would now like to focus on cap-and-trade because that's the innovative part of the policy.

The first permit auction took place in November of 2012 (ARB 2014a). The program currently covers greenhouse gas emissions from electric utilities and industrial facilities with annual emissions greater than 25 million metric tons of CO_2 equivalent (ARB 2011). Other fossil fuels—notably transportation fuels—will come under the cap in 2015, at which point the program will cover 85 percent of California's greenhouse gas emissions. (The policy covers a number of important greenhouse gases and sources, not just fossil CO_2.)

So far most of the revenue associated with cap-and-trade permits has gone back to electric utilities and their customers. Pacific Gas and Electric (PGE), for example, will be providing \$30-\$40 "climate credits" for residential customers twice a year (O'Mara 2014, CPUC 2014). In theory, this should offset the cost of carbon pricing for the average customer, and if the credit is provided as a fixed benefit that is not tied to power consumption, then consumers should still have the appropriate marginal incentives to reduce their power usage. (A numerical example may help, so let's say that carbon pricing raises PGE power prices by 2 cents per kWh, costing customer Joe \$5 a month. If PGE sends Joe a flat \$30 credit twice a year, he doesn't take a hit to his pocketbook but he still has an extra 2-cent-per-kWh incentive to reduce his power usage because the \$30 credit comes regardless of how much power he uses.)

Recent data, from an auction in August 2014 (ARB 2014a), shows a permit price of about \$11.50 per ton CO_2, just above the minimum "reserve price" of \$11.34. (The reserve price started at \$10 per ton in 2013 and goes up annually by inflation plus 5%.) As noted above in the context of the BC carbon tax, a ballpark estimate is that \$10 per ton CO_2 is about \$0.01 per kWh of coal-fired power or about \$0.10 per gallon of gasoline, except of course note that gasoline doesn't come under the cap until 2015.

For comparison's sake, the BC carbon tax is \$30 per ton CO_2. But as noted below the California system may be more comprehensive after the 2015 expansion.

Transportation fuels will enter the cap-and-trade system in 2015. The state intends to auction off these permits and place the revenues in a Greenhouse Gas

Reduction Fund (ARB 2014b). (Assembly Bill 1532 from 2012 requires that 25% of the proceeds benefit disadvantaged communities.) How much revenue will come into the fund depends on the market-clearing price of permits, but the state expects to raise $850 million in the next fiscal year (Gutierrez 2014) and that amount could increase to more like $2 billion a year for the rest of the decade. That's a lot of money, even for a big state like California. With 38 million people, revenues of $1 - $2 billion a year equals $25 - $50 a year for every man, woman, and child in the state.

So let's not beat around the bush: Starting next year, a large portion of AB32 will function like a gas tax in excess of $0.10 per gallon that will fund low carbon transportation, sustainable infrastructure, energy efficiency, natural resource protection, and waste diversion. This may or may not be your cup of tea, but in any case it's obvious that a lot will be riding on the success of the state's investment plan. (The governor wants to use $250 million this year for a controversial high-speed rail project; he also wants the state General Fund to start repaying a $500 million loan that went from the Greenhouse Gas Reduction Fund into the General Fund in 2012 [State of California 2013, Gutierrez 2014].)

A few additional details: First, AB32 specifically includes "carbon by wire", i.e., the carbon emissions associated with electricity generated out-of-state but consumed in California. (Note that the BC carbon tax does not cover carbon by wire. However, both BC and California will mostly exempt fuels for planes and ships: jet fuel, for example, is only included in BC's tax for flights that both begin and end in BC, and the same is true of California's cap-and-trade system.)

Second, AB 32 was upheld by California voters in 2010 and appears to be surviving legal challenges. Proposition 23 offered voters a chance to suspend AB 32 "until unemployment drops to 5.5 percent or less for a full year." By a 62-38 percent margin, voters decided to keep AB 32. And in the courtroom, Marten Law (2013a) notes that the program "has withstood the many challenges it has faced" (see updates from Marten Law [2013b] and Whetzel [2014]) but still faces "a possible dormant Commerce Clause challenge from industry [that] could completely derail [the] cap and trade program." And of course there may be political push-back from voters once gas prices go up.

Finally, note that California's cap-and-trade system is linking with Quebec Province, which has also adopted a carbon cap-and-trade system (ARB 2013), enabling carbon allowances and offset credits to be exchanged between participants in the two jurisdictions' programs. This link will be one of the few remnants of the Western Climate Initiative, an ambitious attempt to create a multi-jurisdictional carbon price across North American states and provinces. A similar effort called the Pacific Coast Collaborative is now in the works, with California's cap-and-trade system battling BC's carbon tax in a friendly competition for regional dominance.

3. Carbon Pricing in Washington State

Significant efforts are underway in Washington State (and in Oregon) to put a price on carbon, either through a BC-style carbon tax or through a CA-style cap-and-trade system. The economics of the two policies are similar—for example, an auctioned cap-and-trade system with a permit price of $30 per ton CO_2 is in most respects identical to a carbon tax of $30 per ton CO_2—so I will describe the relevant issues by focusing on a policy that I have been advocating through the CarbonWA.org campaign to bring a BC-style carbon tax to Washington State.

The gist of our proposal for Washington State is to impose a BC-style carbon tax and use the revenues to reduce sales taxes by a full percentage point, eliminate business taxes for manufacturers, and fund the Working Families Rebate for low-income households. For most households, this will amount to paying a few hundred dollars a year more for fossil fuels and a few hundred dollars a year less for everything else.

Here are some details of the latest iteration of the CarbonWA.org proposal:

- The carbon tax covers fossil fuels burned in Washington State. This is similar to BC, but unlike BC we *will* include all jet fuel and we will also include the "carbon by wire" associated with imported electricity. (Our policy includes a 40-year phase-in for diesel fuel used on farms and for public transportation fuels; there were no similar features in BC's original measure, but more recently the government has added exemptions for agriculture.) All told this will generate about $1.7 billion a year, about 10-15% of state tax revenue.
- The policy will be phased in over time. In Year 1 the carbon tax will be $15 per ton CO_2, accompanied by a 0.5 percentage point reduction in the state sales tax (from 6.5 to 6.0 percent); in Year 2 the carbon tax will be $25 per ton CO_2, accompanied by an additional 0.5 percentage point reduction in the state sales tax (from 6.0 to 5.5 percent). The Working Families Rebate and the elimination of the B&O business tax will occur

immediately in Year 1.

- The carbon tax rate will increase by about 5% per year after Year 2. This is necessary in order to maintain revenue stability (and to provide additional incentives for carbon reductions). With emissions falling at 2% per year and nominal economic growth of 3% per year, a carbon tax increasing at 5% per year will keep pace with sales tax receipts, which increase with nominal economic growth.

The intent of the policy (as with the BC carbon tax) is to combine an "entrée" that provides tax relief broadly across the economy with "side dishes" that provide additional tax relief to highly impacted groups, which in our proposal means low-income households and manufacturers. We also provide a "side dish" for agriculture by providing a 40-year phase-in of the carbon tax for on-farm diesel.

The "entrée" in our proposal is a reduction in the state sales tax from 6.5% to 5.5%. The state sales tax is the largest source of tax revenue in Washington State, generating about $7.2 billion a year. (City and county sales taxes bring the total sales tax rate to something approaching 10% across much of the state.) Note that Washington State has no income tax, so it is impossible to adopt a policy that is exactly like BC's because BC's tax swap focused on reductions in personal and corporate income taxes. (Oregon, which in a mirror image of Washington has an income tax and no sales tax, can come closer to adopting a BC-style policy.)

According to the Washington State Department of Revenue, businesses pay approximately 30% of the state sales tax, so a reduction in sales taxes will provide direct benefits to businesses as well as households to help offset the cost of the carbon tax. (Of course, businesses are likely to pass most of these taxes along to consumers.)

One "side dish" in our policy involves funding the Working Families Rebate to benefit low-income households. This "side dish" is warranted because low-income households may be especially vulnerable to a carbon tax swap: they are likely to spend a disproportionate share of their income on fossil fuels, and some key purchases (such as food and gasoline) are exempt from the sales tax.

The Working Families Rebate (WFR) is a program that has been on the books in Washington State for a few years but has never been funded. It is a state-level version of the Earned Income Tax Credit (EITC), the largest anti-poverty program in the United States. The EITC is something like a Milton Friedman-style negative income tax: if you are low-income and you are working, the Federal government sends you a check to supplement your earned income.

Approximately half of the states have state-level versions of the Federal EITC, meaning that if you get (say) $2,000 from the Federal government, then the State gives you an additional top-up of (say) $500. These state programs are typically connected to state income taxes, but since Washington State does not have a state income tax, the Working Families Rebate is designated as a "sales tax rebate" for low-income households. In practical terms, however, the WFR is designed to operate in the same way as in other states: low-income families that receive an EITC from the Federal government will receive a top-up from the state. Estimates from the Washington Budget & Policy Center indicate that the WFR will provide up to $1,500 a year for up to 400,000 low-income households in Washington State.

The second "side dish" in our policy is effective elimination of the business tax for manufacturers. This "side dish" is warranted because some manufacturers are energy-intensive, trade-exposed (EITE) industries. A steel mill in Washington State, for example, has to compete in a global market with steel mills in other states and other countries. Imposing a carbon tax in Washington State without any additional measures would put EITE businesses at a disadvantage relative to competitors outside the state who are not subject to the carbon tax. For non-EITE businesses this is unlikely to be a problem because one or more of the following are true: (1) energy costs are not a substantial share of firm costs; (2) what energy costs there are will be mostly if not entirely offset by reductions in sales taxes; and (3) the carbon tax will affect all firms in the industry, meaning that they will all have to increase prices and no firm will be at a competitive disadvantage. None of these three statements is true for EITE manufacturers.

The business tax in Washington State is a gross-receipts tax called the B&O tax – the Business and Occupation Tax. We believe that most manufacturers in the state will be better off as a result of the tax swap, i.e., they currently pay more in B&O taxes than they would pay in carbon taxes under our proposal. However, B&O tax information is proprietary in Washington State and so we are trying to find businesses that are willing to serve as case studies. So far the case studies we have done have been promising, but of course we cannot guarantee that a carbon-for-B&O tax swap will benefit all businesses.

Finally, we provide a 40-year phase in of the carbon tax for on-farm diesel used by agricultural operations. This can be thought of as an additional "side dish" and, in part, it is motivated by the same concerns described above for manufacturers: farmers operate in a global market and for the most part will not be able to pass cost increases along to consumers. Although we address this issue by exempting on-farm diesel from the carbon tax, we would much prefer to do with farmers what we did with manufacturers, i.e., reduce other taxes in order to keep the incentive to reduce carbon emissions. Unfortunately, we were unable to find other taxes to reduce: farmers already pay no B&O taxes, no sales taxes on pesticides and fertilizers, and pay reduced property taxes. Providing a long phase-in for on-farm diesel seemed like the best way to address this concern.

For concluding thoughts, I offer up three lessons plus an invitation to join the movement towards carbon pricing.

4. Lesson #1: Pareto Improvements Are Hard

Lessons from Washington State are relevant for other carbon pricing efforts across the country and around the world. One key lesson is about Pareto improvements, which are in many ways the Holy Grail of economic policy. A Pareto improvement is a policy that makes at least one person better off without making anybody worse off, i.e., a policy that might plausibly be adopted by unanimous consent.

Many of the features of our policy are designed with Pareto improvements in mind. Because a carbon tax will impose costs on households and businesses, our proposal provides a reduction in sales taxes that aims to offset those costs. Because a carbon tax will disproportionately affect low-income households and manufacturers, our proposal includes a Working Families Rebate and business tax reductions that aim to offset those disproportionate costs. Because we were unable to find offsetting tax reductions for agriculture, our proposal provides a 40-year phase-in for on-farm diesel.

Despite our best intentions, however, our policy—like almost all economic policy proposals—is unlikely to yield a Pareto improvement in real life. There are always exceptions: people or businesses that engage in a lot of airplane travel, for example, will likely be worse off. More importantly, there are geographic disparities, but the geographic disparities in Washington State are minor compared to those at the national and international levels.

Many observers think that the greatest geographic disparity produced by our proposal will involve transportation fuels, with rural households using more gasoline than urban households. I would argue that this issue is somewhat overstated, with suburban households in particular likely to use just as much gasoline as rural households, if not more.

There is, however, a much more important kind of geographic disparity, and it involves electricity. In Washington State, approximately half of all households are served by public utilities such as Seattle City Light; these public utilities get almost all of their power from hydroelectric dams and consequently would pay almost nothing in carbon taxes. The other half of households are served by investor-owned utilities (IOUs), and in Washington State the three IOUs (Puget Sound Energy, PacifiCorp, and Avista) have a much more carbon-intensive electricity mix than public utilities. Overall, it is likely that our carbon tax proposal will raise the cost of electricity by about 1 cent per kWh for IOU customers and by only 0.1 cents per kWh for public utility customers. (Average power prices in Washington State are around 6-10 cents per kWh, much below the national average.)

Complicating matters even further is that different households use different methods for heating their homes and their hot water: some use electric heat, some use natural gas, some use home heating oil, and some use wood pellets. These disparities are not necessarily geographic, but they do interact with geographic disparities. In particular, a household served by a public utility that uses electric heat will pay almost nothing in home-related carbon taxes; a household using natural gas heating will pay about $100 a year in home-related carbon taxes if served by a public utility and $200 a year if served by an IOU.

5. Lesson #2: Politics is Hard

One could reasonably ask whether $200 a year is a big deal given that average household income in Washington State is about $50,000. A reasonable answer would be that $200 a year could be a big deal for low-income households but is otherwise not that big of a deal for an average household that already pays something like $15,000 a year in Federal and State taxes. But politics is a difficult business, and the appearance of unfairness can be qualitatively important even if it is quantitatively minor.

Polling shows that all carbon-pricing efforts are an uphill battle: not impossible, but an uphill battle. The good news for carbon taxes is they do not appear to be at a disadvantage compared to cap-and-trade systems. The bad news is that voters are hesitant to adopt any kind of economic instruments to address climate change. (They look much more favorably on regulatory instruments like fuel-economy standards even though economists argue that these command-and-control policies have higher costs per unit of emissions reduction than economic instruments.)

Revenue-neutral carbon taxes face an additional political challenge: voters tend not to believe that revenue-neutral carbon taxes will remain revenue-neutral, i.e., they think that "the government" will simply not provide the offsetting tax reductions or will reverse the tax reductions after a year or two, with the net result being an increase in taxes. This problem is not unique to revenue-neutral carbon taxes—voters also do not believe that they will see any money from "dividend" systems that promise to distribute carbon pricing revenue on a per-capita basis to all households—but it certainly threatens the very heart of revenue-neutral carbon taxes, and it does so in a way that is incredibly difficult to respond to. A significant part of the difficulty here is that facts are of limited use. You can say you are going to reduce existing taxes, but voters may not believe you; you can also point out that federal, state, and local taxes as a percentage of GDP have been roughly unchanged for decades (Bauman 2014b), but again voters may not believe you. It is cold comfort that all tax reform proposals run into this skepticism.

6. Lesson #3: Hope Springs Eternal

Despite the challenges, I am still happy to devote what resources I have—time and energy, plus a bit of money—to pushing for a revenue-neutral carbon tax in Washington State.

One reason is that I see a political path forward, and the fact that it is a narrow path does not dissuade me. Revenue-neutral carbon taxes hold the promise of bipartisan support, and in fact are supported by economists across the political spectrum, from Paul Krugman on the left to both of Mitt Romney's chief economic advisors on the right. Revenue-neutral carbon taxes are also supported by many public intellectuals across the political spectrum, including some unlikely advocates like *Washington Post* columnist George Will, who does not even believe in anthropogenic climate change.

(George Will came to one of my classes a few years ago, and I asked him if he would support replacing part of the payroll tax—the employment tax in the USA—with a carbon tax. He said he was all for it, because he hates the payroll tax. And with high unemployment, I hate the payroll tax, too. Al Gore also hates the payroll tax, saying that we should "tax what we burn and not what we earn." So I asked George Will what he thought about the fact that he and Al Gore agreed on this particular issue. He replied, "Well, an idea should not be held responsible for the people who believe in it!") There are also conservative climate champions like former South Carolina Congressman Bob Inglis, who are leading the charge on the right for revenue-neutral carbon taxes.

An additional source of hope for me is that climate action is becoming more of an inevitability, and so the alternative to revenue-neutral carbon taxes is not nothing but rather regulatory approaches (as with the Obama EPA power plant regulations) and/or cap-and-trade systems as in California. I am optimistic that businesses and conservatives will favor revenue-neutral carbon taxes over these alternatives, and I hope that they join the carbon-tax coalition before it is too late.

Finally, I am hopeful because I see very little alternative. To quote Yale economist William Nordhaus from his book *A Question of Balance* (2008), "To a first approximation, raising the price of carbon is a necessary and sufficient step for tackling global warming. The rest is at best rhetoric and may actually be harmful in inducing economic inefficiencies." Revenue-neutral carbon taxes are strongly favored by economic theory and by many economists and thinkers across the political spectrum. As the pressure for climate action builds, a revenue-neutral carbon tax may prove to be the way forward in the United States and across the world. British Columbia has shown the way, Washington State can spread the word, and I am lucky to have an opportunity to do what I can to advance the cause. As we near the 100th anniversary of Pigou's *Economics of Welfare*, the time for pollution pricing to move from theory to reality may be at hand.

And so, I close on an optimistic note, with an homage to Abraham Lincoln's Gettysburg address that I call the Beloitysburg Address, respectfully offered as a tribute to Robert Stavins and to others who are part of the carbon pricing movement:

Beloitysburg Address

Four score and seven months ago brave political leaders brought forth on this continent some new climate policies, conceived in economic liberty and dedicated to the proposition that all external costs should be internalized.

Now we are engaged in a great political war, testing whether those policies, or any policies so conceived and so dedicated, can long endure.

We are met on a potential battlefield of that war, and we have come to dedicate a portion of our lives to honor the work of one who is devoting his life to putting a price on pollution.

The world will little note, nor long remember what we say here, but it can never forget what he has done here.

It is rather for us to be here dedicated to the great task remaining before us—that we here highly resolve that these economic theories shall not have been scribbled in vain——that this nation, under God, shall have a new birth of economic freedom and environmental protection——and that the governments and peoples *on* this earth, *of* this earth, and—whether we like it or not—*over* this earth, shall not perish *from* this earth.

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Regulation, Innovation, and Experimentation: The Case of Residential Rooftop Solar

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I. Introduction

Over the past decade, the residential rooftop solar[3] market in the United States has grown exponentially, with installed capacity accelerating over the past three years. In 2014, a solar system was installed every 2.5 minutes, with the majority of the growth in residential sector with a total of 200,000 systems, up from 50,000 in 2011 (Lacey 2015). Not surprisingly, this growth has not occurred uniformly across the U.S., one reason being different state-level policies.

Reducing barriers to the research, development, and deployment of technologies such as rooftop solar is a generally agreed-upon economic and environmental policy objective. Status-quo regulation of electric utilities, entrenched by a history of inertia and technology lock-in, excludes market entrants who threaten the vertically integrated utility business model, and thus this regulatory and business environment acts as a considerable barrier to entry and innovation (Kiesling 2014). In this paper, we reexamine the growth of the U.S. residential solar market by surveying the intersection of various growth drivers and offering a framework to account for how, and to what extent, these factors fortify or reduce barriers to entry for solar firms and installers. We argue that the growth in the U.S. residen-

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3 The terms “rooftop solar” “photovoltaic” and “PV” will be used interchangeably throughout this text.

tial solar capacity is a consequence of intersecting layers of institutional experimentation, some of which facilitates market experimentation by both electricity suppliers and consumers.

Recent innovations in smart grid and distributed energy technologies, innovations in solar industry financial and business models, and utility concerns about their financial viability in the face of such innovations, motivate our analysis of the regulatory institutions and their features that may be conducive to lower barriers to innovation in electricity. Here we take residential rooftop solar as a case study that should, with subsequent research and analysis, continue to shed light on the burdens and opportunities facing technologists, entrepreneurs, policymakers, and regulators attempting to orchestrate more efficient, dynamic, resilient, and clean electricity markets.

Broadly, we identify four sets of experimentation factors that drive solar market growth, (though we acknowledge their applicability beyond the scope of this particular subsector). These factors include technological innovation, financial and business model innovation, regulatory change, and "exogenous factors." Table 1 summarizes these factors with examples from the solar sector.

Table 1: Residential Solar Market Growth Drivers

Factor category	**Example**
Technological innovation	Falling costs (in hardware manufacturing: PV modules, inverters, etc.; in soft costs: financing, installation, customer acquisition; a consequence of economies of scale, firm learning, and global competition), enabling technologies (digital smart grid technologies, energy storage)
Financial and business model innovation	Solar ownership models: power purchase agreements (PPAs),[4] leases,[5] and loans[6]
Policy/institutional framework	Solar policies: net metering,[7] interconnection agreements,[8] renewable portfolio standards (RPS),[9] tax credits, feed-in-tariffs[10]; regulatory context: market design (vertically-integrated electric utility, restructured market w/o retail competition, restructured market with retail competition. Each influences the legal and regulatory status of solar entrepreneurs and can act as an entry barrier.
Exogenous factors	Environmental policy, climate change, "energy independence," long-term energy supply and economic activity

4 A Power Purchase Agreement (PPA) is a financial agreement between a customer who wants an on-site solar electricity installation and a third-party developer who owns, operates, and maintains the solar system. The host customer-generator agrees to site the system on its roof and purchases the system's output for a period of 20 or so years. The customer procures stable, and sometimes lower cost, electricity from their solar system, while the third-party developer benefits from tax credits as well as income from the customer-generator's purchase of power.

5 With a solar lease, a homeowner leases solar panels at a flat monthly fee without upfront costs over a period of 15-25 years. At the end of the contract, the lessee may renew the contract, purchase the system, or have the panels removed.

6 Solar loans are a relatively new innovation in the solar financing. The terms of solar loans tend to mimic those of a power purchase agreement, as homeowners pay back the loan with per kWh generated payments. Solar loans allow customer-generators to claim the 30% federal tax credit, and, unlike a PPA, ultimately own their system.

7 Net metering: solar panels, for instance, are connected to a public-utility power grid and surplus power is transferred onto the grid, allowing customers to offset the cost of power drawn from the utility. The solar owner is generally compensated at the retail rate of electricity for surplus power.

8 The process of physically linking solar panels to the power grid.

9 Usually a state-level policy, a renewable portfolio standard (RPS)mandates that a certain percentage of electricity produced comes from renewable generation.

10 Solar power is sold to the grid at a pre-defined per-kWh rate of compensation, often exceeding the retail cost of electricity

In Section II, we describe and analyze the technological and financial innovations and the institutional framework driving residential solar market growth. In addition to the 30% federal tax credit for solar, many states simultaneously employ multiple renewables policies. California is the primary case study in our analysis, as in the past 15 years the State has exemplified the use of a renewable portfolio standard, net metering, feed-in tariffs, and some direct subsidy programs such as grants and rebates. Either individually or in combination, none of these policies is designed to or able to target some theoretical, optimal size of the residential solar market; they also do, to some extent, fall prey to the criticism that they are distortionary policies that subsidize particular technologies that may or may not be long-term technology "winners". Yet we can compare across these various policies and inquire into which are, by a relative measure, more likely to facilitate market experimentation by reducing barriers to innovation at the margin (and, conversely, erode the inertia and technology lock-in of incumbent utilities). Two policies that have shaped California's institutional context are net metering and the renewable portfolio standard (RPS). Compared to direct, targeted technology subsidies or mandates, net metering and the RPS are relatively more flexible and technology-agnostic, and allow for more market experimentation by both producers and consumers in the burgeoning residential distributed generation market.

In the 1990s, the generating capacity of solar remained negligible within the broader U.S. electricity mix. However, other technology and policy changes in the electricity industry were laying the groundwork for future solar growth and, indeed, set the course for many of the challenges and opportunities for distributed energy resources in U.S. retail electricity markets. Here we analyze the intersection of a number of structural, regulatory, technological, and financial changes to the electricity industry that influences the viability of distributed energy resources (DER), in particular residential rooftop photovoltaics. Our primary interest is in analyzing electricity regulation, state policies, solar business models, and solar financing as various *strata of experimentation*, and how these various strata or layers intersect to influence the success or failure of distributed energy resources, in particular residential rooftop solar in California. We then present a framework for analyzing how these factors relate to either reduce or strengthen barriers to entry into the renewable electricity industry to firms or potential solar customers. Policies that enable market experimentation are most conducive to the innovation process that can create electricity that is simultaneously economic and cleaner.

Such policies reduce barriers to market entry, enable retail competition, and are by definition technology-agnostic.

II. The U.S. Residential Rooftop Solar Market

A. The Current State of Residential Rooftop Solar PV in the United States: The California Case

The residential solar market has grown substantially over the past decade, through a combination of technology, market, and policy drivers. Three-quarters of U.S. utility, commercial, and residential-scale PV systems went online between 2011 and the first half of 2013 (GTM Research 2013). The installed cost of distributed photovoltaics fell 44% between 2009 and 2014, with distributed solar installations comprising 31% of all electric power installations completed in 2013; in that same year, overall residential solar PV capacity increased 68% across the nation. California led this growth with a 161% increase in 2013. However, excluding the growth in California, in the rest of the U.S., residential installations were in fact 18% lower in 2013 than in 2012 (Sherwood 2014).

Historically, strong state policies supporting solar PV in California have inspired investor confidence and provided financial support for the industry. As a result of the Public Utilities Regulatory Policies Act of 1978 (PURPA), the rise of generators using renewable energy sources showed that there were reliable sources of power other than large-scale centralized generation owned by a vertically-integrated firm. PURPA catalyzed early development of the solar industry in California more than in other states, and paved the way to make any future energy generation venture worthwhile, insofar as it could successfully bid into California's wholesale electricity market. The renewables policies currently in use in California include a renewable portfolio standard (RPS), California Solar Initiative subsidies, net metering, and feed-in tariffs. The organizational structure of regulated distribution utilities in California as monopolies without competition directly truncates the extent to which experimentation may occur on the network: while wholesale electricity generation is open to any supplier, parallel retail market processes are not available.

In 2002, California enacted its Renewable Portfolio Standard (RPS) targeting a 20% renewables mix by 2010. Legislation to reach 33% renewables failed in

2009, and in response later that year, Executive Order S-21-09 required the California Air Resources Board to develop a renewables program to reach a 33% RPS before 2020. In 2011, new legislation codified the 33% requirement with interim targets in 2013 and 2016 (DSIRE 2014). In the event of non-attainment, the California Air Resources Board is authorized to penalize non-compliant utilities.

In addition to the strong RPS mandate, in 2014 the California Solar Initiative (CSI) closed two years ahead of schedule. The California legislature created the program in 2006 with the aim of putting solar on 1 million roofs in California – 1,940 megawatts of residential and commercial projects by 2016 through $2.3 billion in taxpayer-funded cash-back incentives (DSIRE 2014). Even though the allocated funds were exhausted, total installs have exceeded the capacity targets by "hundreds of megawatts … 72 percent of all residential solar projects in the state were completed without any state incentives in the second quarter of 2014. California installers will deploy more than 1 gigawatt of residential and commercial projects this year, the majority completed without the help of the CSI incentives" (Lacey 2014). The program differs from other rebate programs, importantly, by reducing subsidies volumetrically as more solar capacity comes online, benefitting first movers while transitioning the industry slowly to a lower-subsidy marketplace The quiet success of the CSI demonstrates a way that states can ramp down subsidies as commercial activity grows around technology.

California also has one of the oldest and strongest net metering policies in the United States. A net metering policy requires the distribution utility to buy or credit owners of distributed generation for supplying their excess energy to other users on the distribution network, and stipulates the administrative price at which purchases will occur. First enacted in 1996, then reauthorized in 2008 and 2013, the current policy limits individual system capacities to 1 MW, though local governments and universities may apply to net meter systems up to 5 MW. In 2006, legislation increased the cap on net metering in a utility's service territory from 0.5% to 2.5%, and again in 2010 from 2.5% to 5%, of the utility's "aggregate customer peak demand." Calculations of "aggregate customer peak demand" differed among the three California utilities (SDG&E, SCE, PG&E[11]), and so in 2014 AB

11 San Diego Gas and Electric (SDG&E), Southern California Edison (SCE) and Pacific Gas and Electric (PGE). San Diego Gas and Electric (SDG&E), Southern California Edison (SCE) and Pacific Gas and Electric (PGE). PGE's service territory covers the majority of the northern part of the state, except for the Sacramento area (serviced by the Sacramento Municipal Utility District). SCE's territory extends throughout Southern California, except for, of course, San Diego, and some smaller electric co-ops.

327 codified a uniform methodology to calculate this number.[12]

Utilities must offer net metering to customers either until it reaches its cap, or until July 1, 2017, at which point utilities must offer a standard tariff for new customers selling power to the grid. In other words, once net metering is exhausted, the California Public Utilities Commission (CPUC)–the state's utility regulatory body–will require utilities to develop a standard contract for new and existing customers to sell power to the grid.

Net excess generation is carried forward to the customer's next bill. At the end of each 12-month period the utility is granted remaining credits. Importantly, the net metering legislation in California explicitly prohibits utilities from charging customer-generators any fees that other customer classes would not bear (such as demand, standby, minimum, or interconnection charges). However, this language suggests that charges such as a minimum bill are not prohibited if such charges were to be levied against all customers classes (not just those who net meter).

CPUC has also approved time-of-use rates with net metering ("co-metering"). However, each utility can decide whether or not to offer this pricing.

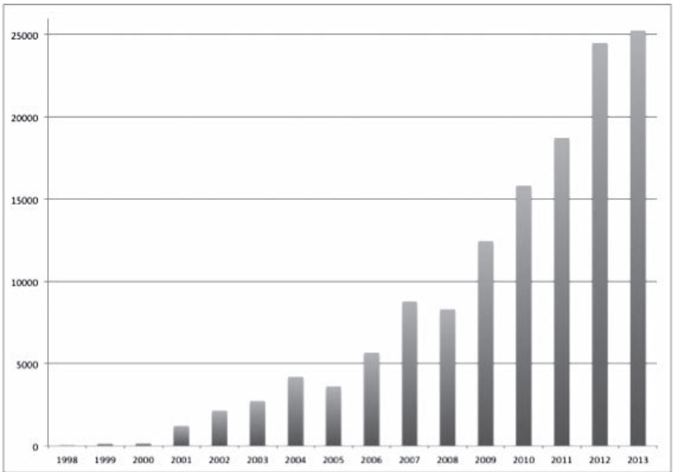
In July 2007, CPUC required PG&E and SCE to develop and offer feed-in-tariffs[13] for eligible renewables technologies. Over time, these tariffs were expanded to all investor-owned utilities, and multiple amendments increased the individual and aggregate capacities of the tariff program. All investor-owned utilities and public utilities with more than 75,000 customers were required to create a standardized feed-in tariff available to their customers as a mechanism for RPS compliance. The utilities offer customer-generators a per-MWh contract for 10-, 15- or 20- years for systems up to 3 MW. The tariff prices were based on previous auctions for renewables from November 2011, and then adjusted based on acceptance or decline of offers from utilities by customer-generators. These prices adjust every two months until 50% of the total targeted installed capacity is met, meaning there is a feedback loop in place to ensure that feed-in-tariffs are properly priced to meet renewable capacity goals.

Figures 1 and 2 indicate the growth and the cost reductions seen in the residential solar industry in California.

12 If not otherwise noted, data on California's renewables incentives are from the DSIRE database.

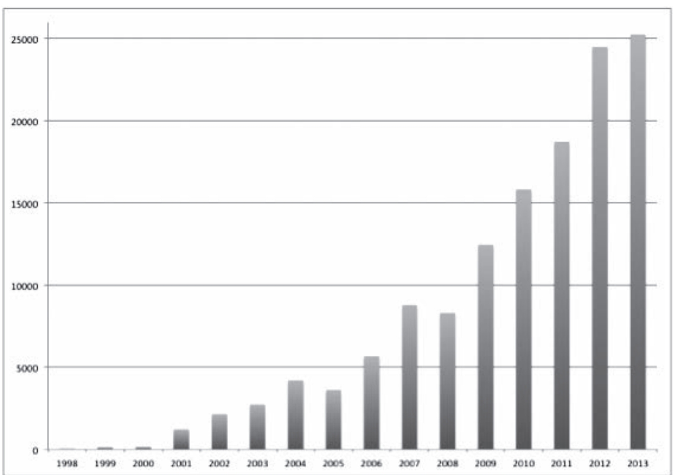
13 Feed-in-tariffs are a performance-based incentive for renewable energy production, where a customer-generator is compensated at a pre-determined rate for electricity sale. These contracts are long-term, allowing prospective customer-generators to accurately predict cost savings or revenues over the lifetime of renewable systems.

Figure 1: Number of new ≤ 10kW solar installations, annual, California



Source: Lawrence Berkeley National Laboratory (2014)

Figure 2: Median installed cost for <10kW projects ($/W), annual, California



Source: Lawrence Berkeley National Laboratory (2014)

California led the nation in installed PV capacity in 2013 with 2,478 MW[14], followed by Arizona, North Carolina, Massachusetts, New Jersey, Hawaii, Geor-

14 MWac, assuming 5% losses from DC to AC inversion.

gia, Texas, New York, and Maryland accounting for a total of 1,470 MW, or 33 percent of installed capacity. All other states combined for 437 MW in 2013, or 10% of installed capacity (Sherwood 2014). The overall residential solar PV market grew 38% between 2013 and 2014, with the top 10 installers growing 75% compared with 12% growth among all other installers. Not surprisingly, of the top ten residential solar PV installers in the United States (which combined account for more than 50% of the market), four of the top five have headquarters in California (SolarCity, Sungevity, Verengo, and Solar Universe). SolarCity led installations with 29% of the market share, followed by Utah-based Vivint Solar at 9% (Munsell 2014). Both companies are publicly traded as of 2012 and 2014 respectively (Wang 2014, Nasdaq n.d.).

California's regulation of the residential retail solar market maintains the distribution utility's monopoly over the provision of electricity service to residential customers. By removing a customer's opportunity to choose among retail service providers, such regulation undercuts the ability of consumers to experiment and learn about value propositions that might be welfare-enhancing other than the ones that the monopolist offers and the regulators approve. The lack of retail choice constitutes a legal entry barrier against competing retail service providers. Likewise, such regulation also stifles the development of differentiated products and services that consumers may find valuable. However, the CPUC does allow distribution utilities to offer a differentiated rate tariff, with time-differentiated rates and specific contracts for demand response and direct load control programs.

The retail regulatory feature that allows for consumer experimentation even in this monopoly context is the inability of the regulated monopolist to block "behind the meter" installations of consumers. The footprint of the regulated distribution utility stops at the meter, leaving the consumer free to choose what energy investments to make in the home. Combined with the solar-specific policies described above, this boundary of regulation created the opportunity for the residential solar market in California to develop out of its historical roots.

B. Technological Innovation, Financial Experimentation, and Solar Soft Costs

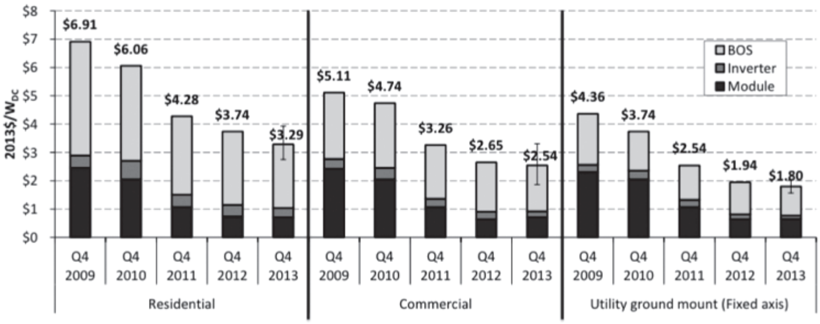
Whether they internalize an environmental cost or over-stimulate supply or demand, government policies do drive cost reductions for technologies, spur demand, increase supply, and decrease the cost of capital for entrepreneurs commercializing and marketing these technologies. This feedback loop between the public and private sectors, combined with research-driven energy efficiency improvements in PV technology, has contributed to cost reductions in technologies as a consequence of economies of scale and other efficiencies and innovations. The U.S. Department of Energy estimates that installed prices of solar decreased 6-7% per year from 1998-2012 and 12%-15% from 2012-2013. (Friedman, et al. 2013). The modeled system prices for installations in early 2014 was $3.29/W for residential (Feldman , et al. 2014).[15]

Analyst expectations suggest that by 2015 some residential systems will be installed at a price below $2/W, with the global module price index remaining stable, and major cost reductions coming from reduction in soft costs such as customer acquisition[16], as well as possibly lower cost of capital and streamlined regulatory procedures. Where precisely these "soft cost" savings will be is unclear, though undoubtedly with increased competition among residential solar providers, companies will be forced to find cost savings within their own business, rather than capitalizing on first-mover customers or regional familiarity. To illustrate this point, Figure 3 presents estimates of PV system prices for residential, commercial, and utility-scale installations. Note the sharp decline in module prices between 2009-2011, followed by flattening in 2012 and 2013. The yellow "balance of system" (BOS) or "soft costs" box has remained relatively static between 2009 and 2013, when compared with cost savings in modules and inverters. As the inverter market grows more mature and commoditized, costs will decrease as well. Firms are recognizing the value of reducing cost of customer acquisition, which is at present approximately $0.49/W; between 2014 and 2017, streamlining customer acquisition is likely to reduce those costs by roughly $.14/W (GTM Research 2013).

15 Module prices refer to the cost of photovoltaic panels alone, measured in capacity (i.e. the maximum amount of energy the module could produce), and traded as a commodity on global markets. Conversely, there are many ways to measure all-in system costs, which generally include the cost of modules, permitting, installation, labor, inverters, and other costs associated with setting up a solar PV system. Some analysis of system costs is reported by the solar industry itself, or costs can be estimated using a "bottom-up" approach, where various assumptions and costs are added to estimate a theoretical system cost.

16 Cost of customer acquisition refers to the expenses incurred by businesses to convince a customer to purchase a product, such as research and marketing.

Figure 3: *Bottom-up Modeled System Price of PV Systems by Sector, Q4 '09 - Q4 '13*



Source: (Feldman , et al. 2014)

C. Financial Innovation: Third Party Financing

The growth of rooftop residential solar markets is a consequence not only of flattening module prices and reduced soft costs, but also of financial innovation. Traditional ownership of solar PV entails significant financial and transaction expenses for a homeowner, including upfront cost of installation, equipment, operations, and maintenance. Third-party ownership allows developers to cover most of these expenses, and then be paid back over time through the sale of electricity directly to the customer-generator. These innovations have allowed customers to lock-in low-cost electricity with 20+ year contacts, which often include operations and maintenance. Customers no longer face the large upfront capital expenses for solar installations, and instead outsource much of the installation and operations process to third-party installers. Third-party ownership models such as leases and power purchase agreements (PPAs) dominated all subsectors of new solar capacity in 2013 (Sherwood 2014). The Solar Energy Industries Association finds that:

- More than 90 percent of New Jersey's residential solar market has consisted of third-party owned systems since Q2 2013.
- In Q1 2014, more than 50 percent of New York's distributed generation systems were third-party owned, and in California, Arizona and Colorado, 69 to 81 percent of installed distributed generation systems were third-party owned (SEIA n.d.).

According to a study of the Southern California solar market, third-party ownership is correlated with adoption by younger, less affluent, less educated populations than those customers purchasing systems outright (Drury, et al. 2011), implying that third-party ownership increases the total demand for photovoltaic systems rather than displacing demand from customers who would have otherwise purchased systems. The main causal mechanism is the extent to which third-party ownership decreases barriers to adoption, including upfront costs and technology risk and complexity. Around 20 states allow third party ownership.

These financial innovations in the solar sector present three types of challenges to the regulatory status quo in most of the United States (Kollins, Speer and Cory 2010). First, what is the definition of an electric utility? The states of Colorado, New Mexico, and California have each explicitly exempted third-party ownership structures from PUC regulation by declaring they are neither utilities nor electrical corporations. Second, is power generation equipment as such an electric utility? Nevada and Oregon explicitly exclude third-party owned renewable energy systems from utility regulation. Finally, what is the definition of an electric service provider? In regulated or hybrid-restructured states, utilities are often defined as organizations offering "electric services", so firms that do not provide electric services are not utilities. In Oregon, for example third-party owned systems are *not* considered competitive suppliers insofar as these systems do *not* provide ancillary services to the grid. (Kollins, Speer and Cory 2010)

In response to these and other regulatory issues, Kollins et. al. argue for a number of alternatives to third-party PPAs including solar leases. Leases allow customer-generators to lease solar equipment from companies and to then receive the power generated from that equipment. This model is a popular option in Florida, for example, where third-party power-purchase agreements (PPAs) are forbidden. Other institutional barriers remain as well, including Florida's lack of net metering and lack of solar contractors, and training, certification, inspection, permitting, and building code rules (Soskin and Squires 2013). Yet despite the lack of incentives and regulatory structure, Florida ranks among the lowest installed-cost of residential solar systems. These inconsistencies deserve further investigation. As Will Craven of SolarCity puts it, Florida remains the "sleeping giant" of the solar industry (Smith 2014). At a national level, solar leases are building momentum. As of Q1 2013, third-party financing for residential installations accounted for 50% of new capacity in California, Arizona, Colorado and Massachusetts, with the model gaining greater market share in other states such as Connecticut, Delaware, Maryland, New Jersey, New York, Oregon, Texas, Vermont, and Washington (Kann 2013).

A third financing innovation has been solar loans. SolarCity's new solar loans program is expected to serve approximately 50% of their clients in 2015 (Wesoff 2014). Solar loans resemble PPAs but allow homeowners to own the solar panels and take advantage of the 30% federal production tax credit. In theory, solar ownership should cost less than PPAs or leases by opening solar project financing to a larger pool of institutional investors such as banks, who offer homeowners better loan terms than a tax equity investor. In addition, new research out of Lawrence Berkeley National Lab concludes that owning solar systems increases the resale value of homes by $4 per watt on average (Hoen, et al. 2015). Offering loans allows solar companies to compete in states that forbid third party financing (Wang 2014). In April 2014, a survey of California homeowners found that 60% would prefer to own their rooftop solar systems, a finding compatible with solar loan financing (Wesoff 2014).

D. State Support for Residential Solar PV: Lessons Learned

In their SEC filings, SolarCity notes that treasury grants, federal and state tax credits, electricity rate design, customer fees and charges, limits on net metering, interconnection standards, the retail cost of electricity, and other government and utility policies greatly influence the residential solar industry's cost of capital, and therefore competitiveness with utility electricity (SolarCity Corporation 2013). For installers, in short, subsidies reduce the cost of capital by inspiring investor confidence that there is and will be demand for solar products. In turn, solar installers pass the savings from both government subsidies and more favorable financing terms from banks and investors on to solar customers. How a reduction or abandonment of the 30% federal tax credit would influence these installers remains unclear. Unlike the wind industry, which General Electric, Inc. has declared competitive without a federal tax credit, the solar industry remains fearful of regulatory, market, and government changes that influence the viability of solar PV (Pyper 2014). These battles have been particularly visible in markets like Arizona and Wisconsin, where utilities have proposed fixed fees and taxes that reduce the value of solar (Lacey 2014, Newman 2014).

The issue in these states is cross-subsidization. Under the traditional utility regulatory compact, all costs associated with the vertically integrated electric utility – generation, fuels, transmission, distribution, billing, etc., are bundled and then divided by kWh-sold to derive a volumetric price of electricity. Those advocating fixed charges for solar customers argue that solar customers, who are compensated via net metering for each kWh produced at that retail rate of electricity, are relying on the distribution network and other infrastructure for reliable delivery of power and a market to sell their net-generation, while not paying their share of costs associated with those services. Proposals to levy a fixed fee on customer bills to compensate for grid and other fixed costs attempt to quarantine variable from fixed costs. On the other hand, the business model for residential solar PV hinges on net metering, and any reduction in the per-kWh retail rate of electricity diminishes the profitability of solar products for customer-generators and the solar companies themselves. These differences are causing considerable tension as changes reveal the mismatch between traditional regulatory institutions and heterogeneous technologies.

In the United States, net metering remains the bedrock of solar PV incentives. In 2013, 95% of all distributed installed capacity of solar was located in states with net metering policies (Sherwood 2014). Krasko and Doris (2013) argue that net metering, along with transparent interconnection requirements and prices, form the first tier of a multi-tier solar penetration policy. Stoutenborough and Beverlin (2008) show that net metering, unlike direct incentives like grants, tax credits, and rebates, places the economic cost of distributed energy production on the utilities themselves (and thus in part on electricity ratepayers) rather than taxpayers at large.

E. Perverse Incentives, Impacts on the Utility Sector, and New Market Schemes

Many privately owned solar projects in the United States are exempt from federal regulations because installations are certified either as "Qualifying Small Power Production Facilities" under PURPA, or as "Exempt Wholesale Generators" under the Public Utility Holding Company Act of 2005 (SunEdison, Inc 2014). As a result, these facilities do not come under the Federal Energy Regulatory Commission's jurisdiction, and are exempted from federal and state laws that govern the regulation of electric utilities. Though insulated from direct regulation, the solar industry in the United States is still indirectly subject to various regulatory risks.

Investment risk and uncertainty for solar customers falls into at least three categories: 1) solar resource variability, 2) technical performance and maintenance, and 3) regulatory/market risks from future electricity rates and restructuring (Drury, Jenkin, et al. 2013). Solar customers, and installers as well, tend to think about returns of solar investments as fixed points such as payback time, savings on electricity bills, and others. Yet with a 20-30 year lifespan, solar projects remain vulnerable to changes in markets and solar performance throughout the project. For example, persistent weather events like La Niña can cause annual PV performance deviation up to 15% from the mean, although these events tend to even out over the lifetime of projects. Greater risk can be assigned to the degradation of PV systems, which tends to decrease performance by 0.5%-0.7% per year. Similarly, future operations and maintenance costs remain unknown in the future. At present, system maintenance costs owners around $5/kW per year, but unwarrantied products, particularly inverters, can raise costs up to $15/kWdc per year. However, most states and third-party installers tend to use warrantied products, decreasing the risks associated with equipment failure. In analyses of risks, both internal and external, regulators must be aware of the impacts their changes have on the economics of future as well as existing solar systems. Though most environmental policies around rooftop solar focus on a particular capacity target, future regulatory changes, perhaps outside the realm of environmental policies, may dramatically alter the success of previous efforts. Just as technology lock-in from the past 100 years has eroded opportunities for technological progress in the vertically integrated utility, we should be equally wary of present-day policies that codify advantages for particular distributed energy resources, rather than laying a groundwork for technology experimentation.

Changing market dynamics are a double-edged sword for PV projects, though. Residential solar PV helps hedge some market risk, such as electricity price volatility, environmental policies, or changing utility models. However, the assurance that PV can provide entirely depends on the stability of net metering policies. Some proposed rate structures significantly modify the value of PV by abandoning net metering at the retail rate. These restructurings revalue rooftop PV to around 7 cents per kWh, well below the U.S. average retail rate (Drury, Jenkin, et al. 2013). For example, California utilities have been proposing to merge various rate tiers that make solar PV less valuable to customers paying higher electricity rates.

As Darghouth et al. (2011) conclude, at least in California, bill savings per kWh of installed PV varies by a factor of four across customers as a consequence of the inclining block rate structure (under which customers pay higher unit prices the more they have consumed). This implies that, under current market dynamics, customers who consume more electricity are always rewarded more on a per kWh-generated basis than customers consuming less power. As a result, the policies put in place to protect low-consumption customers create a perverse incentive for this customer class *not* to reap the benefits of solar installations and vice versa (Darghouth, Barbose and Wiser 2011). In contrast with some other opinions, Cai et. al. (2013) argue that these restructurings imply the need to abandon net metering, and to replace it with a "value of solar tariff", as proposed for example by Austin Energy, Rocky Mountain Institute and others. Value of solar tariff proponents emphasize how generation and consumption of electricity ought to be metered separately, and customer-generators should be compensated not only for their energy value at the retail rate (per net metering), but also for other benefits including net avoided infrastructure costs and the environmental attributes of solar.

California's solar policies have set clear priorities for the state's procurement of renewable power. While setting market preparation policies, including interconnection and net metering standards, and preempting utility actions to devalue solar installations such as fixed fees, the state's increasingly stringent RPS, coupled with a strong regional solar industry and a variety of incentive programs, contribute to the state's robust market for residential solar power. It is also a state where the diversity of experimentation in technology, solar business models, and financing coincide with experimentation with policy drivers for renewables. These policies have also exposed internal shortcomings of the traditional electric regulatory scheme.

III. Regulation, Experimentation, and Innovation

The above analysis describes the recent growth in the residential solar market, especially in California, and the types of policies that have driven the growth in the California markets, as well as others across the United States. Table 1 identified policy change as one growth driver or inhibitor in the residential solar market. This table provides a conceptual schema for understanding the various overlapping realms of potential experimentation, but the details matter. Not all renewable portfolio standards are equal: their specific rules, implementation, and assumptions influence outcomes. For example, a renewable portfolio standard (RPS) that specifies the installation of a particular technology (e.g., utility-scale concentrated solar) by a specific type of market agent (e.g., the regulated distribution utility) would stifle the type of physical and financial innovation seen in the residential market.

Residential rooftop solar possesses several benefits, some of which satisfy policy mandates, and others that do not. For example, if state policies are aimed solely at meeting greenhouse gas mitigation targets, they ought to incentivize lowest-cost decarbonization (e.g., geothermal) rather than rooftop solar systems under 10kw capacity, which tend to be more expensive on a levelized cost of energy basis. However, the appeal of these policies often is not merely the environmental attributes: rooftop solar systems give homeowners greater independence, insulate them from future increases in the cost of electricity, and may provide aesthetic and social goods. The economic and environmental benefits and costs of any specific energy technology will change over time, as innovation and culture lead to changes in the (subjective) opportunity cost of each technology. Thus more technology-agnostic policies that do not reward or lock in specific existing technologies are more likely to be conducive to long-run sustainability in achieving policy objectives through experimentation-generated innovation. A more technology-agnostic and source-agnostic policy would create less of a barrier to innovation, and may reduce the taxpayer costs of these policies. Similarly, a residential retail market open to competition is likely to be more conducive to the type of product differentiation to attract diverse customers that would induce innovation, as well as trial-and-error experimentation by consumers.

Regulatory institutions can either enable or hinder innovation. The economic and policy environment in which the residential rooftop solar market is developing in the US is a complicated one, with both organic and artificial drivers (as seen in Table 1 and described above). Two dimensions of regulatory policy interact in the residential solar market – renewables policy and retail market regulation. Renewables policy refers to the source-specific policy context in which producers decide whether, what, and how much to bring to the solar market, and consumers decide whether, what, and how much to buy.

The policy environment in the electricity industry is complex and historically rooted. The industry faces regulation at both the federal and state levels, and an increasing synthesis of traditional economic regulation and environmental regulation at both levels. Government intervention has played a role in electricity for over a century, based both on social policy objectives of universal electrification and reliability, and national policy objectives of energy security. There currently is, and almost always has been, government intervention in the electricity industry, including policies over the past decades to subsidize the development and commercialization of every electricity generating technology.

Consequently, regulatory policy in electricity aims at multiple objectives using an accretion of multiple policy instruments: rate-of-return regulation of distribution wires utilities, the perpetuation of residential retail market monopoly in some states, and a panoply of renewables policies and programs ranging from the federal tax credit to state renewable portfolio standards to local tax exemptions for community solar. An idealized intervention-free electricity market simply does not exist.

Taking the multifaceted policy objectives and this complex environment as given, including the array of pre-existing solar subsidies, here we grapple with a more circumspect question: what is a useful conceptual framework for analyzing the variety of state-level solar-related policies in practice? In this framework we prioritize the policy objective of facilitating dynamic, forward-looking innovation in a cost-effective and resilient way, which means looking for dimensions of policy that reduce barriers to innovation but do not necessarily "pick winners" or subsidize specific technologies that may or may not be economically and environmentally sustainable.

Research, development, and commercialization of new technologies, products, and services necessarily involve duplication of efforts, false starts, and dead ends (Mokyr 2010). One of the greatest dynamic benefits generated through market processes is the trial-and-error learning that can lead to a new product's success or failure; market enterprise is a system of profit and loss, and failures and false starts in markets lead to error correction that makes the innovation process as cost-effective as is feasible. Progress toward cleaner and more energy efficient electricity is rarely predetermined or linear. Policy makers striving toward the objective of cleaner and economical electricity have to balance attempting to accelerate innovation while not wasting taxpayer resources, and they have to achieve that balance in the face of their epistemic and cognitive limits -- they cannot replicate the diffuse private knowledge that exists and is created in the interactions of distributed individual agents in the economy, both in the processes of exchange and the processes of research and development.

For those reasons, we take as our conceptual benchmark the extent to which a policy fosters *experimentation*. Experimentation means undertaking actions to discover something unknown, and is the hallmark of how market processes create value in a dynamic rather than a static sense (Kiesling 2014). When an entrepreneur develops a new product or service and brings it to market: that is an act of experimentation. When a consumer walks in to a store, explores what mobile communication devices are available, what features they have or lack, and their prices: that is an act of experimentation. When enough consumers choose a specific product and get consumer surplus from that choice, the producer profits; when consumers do not choose a product, or choose it and don't end up getting consumer surplus, the producer earns a loss, and error correction will involve either changing the production process and price, changing the product, or leaving the market. The interaction of producer and consumer experimentation through market processes over time yields commercial innovation, an example of which being the compound consequences of the Industrial Revolution (Mokyr 2010).

Policymakers interested in cleaner, economical electricity aim to influence this process to achieve their policy objectives. If the policy objective is to advance cleaner and more economic energy technologies, a problem of more prescriptive policies is that they limit experimentation. Policies that stipulate specific technologies that will be eligible for subsidies may induce growth in those technologies, but there is an unseen opportunity cost: the other technologies that could have been developed that may have been even cleaner, more economical, or more attractive to consumers. Policies imposing technology mandates stifle this dynamic experimentation process before it has even started, substituting policymaker judgment for the judgments of all of the producers and consumers subject to their control. Prescriptive technology policies narrow and focus the channel of innovation. That focus may yield some production economies of scale in the chosen technology, but at a cost of cutting off possibly beneficial exploration. Thus we can evaluate the terms of the multitude of state-level solar-related policies active in a state like California based on the extent to which they foster the kind of decentralized experimentation, of both producers and consumers, as in the idealized dynamic market process described above.

Policy goals such as capacity targets for renewables are an attempt to guide an already perverse and distorted regulatory electricity market. The extent to which electricity markets foster innovation and experimentation, we argue, should be a specific objective of future electricity market reform, and is not intended as a disparagement of existing policies. Policy makers are beginning to incorporate these values into future regulatory changes, most notably in New York.

One important caveat against such regulatory policy activity, though, is the "knowledge problem" critique typically associated with Austrian economics. In particular, regulation stifles the social learning that occurs through experimentation that happens in market processes. The learning aspect of market processes is crucial for enabling economic and social coordination, because knowledge is diffuse among the individual agents in society (Hayek 1945, 1974). With diffuse private knowledge, neither entrepreneurs nor policy makers can know what goods and services will succeed with consumers, and at what prices. Similarly, consumer preferences are not fixed and known *ex ante*, either to others or to themselves. Consumers only learn their own preferences through the process of evaluating available choices against each other, and the relative value of those tradeoffs changes over time and as the set of available choices changes due to entrepreneurial activity. Thus by extension, no policymaker or regulator can access such tacit knowledge created in the minds of individuals. Only in the process of evaluating the tradeoffs and opportunity costs in their electricity consumption decisions do individual consumers learn their own evaluation of those opportunity costs, and that knowledge is unavailable to bureaucrats or regulators except through transactive market activity.

The underlying theory and practice of regulation within the electric utility industry so far does not consider experimentation processes that convert creativity, innovation, and technological change into new value propositions for consumers, perhaps revising market boundaries and creating economic growth in the process. Experimentation is among the most substantial drivers of value creation in an entrepreneurial theory of competition that emphasizes competitive market processes—the ability of producers to bring new ideas to market, of producers to combine and bundle existing and new products and services in novel ways, and of consumers to discover these new value propositions and learn how much to value them. Yet despite the clear benefits, these concepts have not yet been integrated into the electricity sector. Rogers (1962) identifies experimentation as one of the primary factors influencing the diffusion of innovation. Greenstein (2008, 2012) argues that economic experiments played a significant role in creating value in the markets for Internet access; his analyses suggest that although economic experimentation is a driver of value creation, pre-1990s Federal spectrum policy erected a regulatory barrier to such experimentation. The technological, entrepreneurial, and regulatory parallels between the Internet and the electricity industry are stark.

Competition creates value through trial and error while exploring new technologies, innovations, business models, product differentiation, and commercial and profit opportunities. Both producers and consumers are entrepreneurs insofar as they discover new profit opportunities through their alertness. This experimentation-based theory of competition combines the Schumpeterian disruptive entrepreneur who generates creative destruction with the Kirznerian alert entrepreneur who interacts with those changes.

Schumpeter's (1934) pioneering work examines how disruptive innovation creates economic growth via individuals who create "new combinations" of materials and forces, leading to change away from economic equilibrium (1934, p. 65). Individuals come to discover these "combinations" by experimentation. Existing producers differ from these experimenters in their tendency to initiate dynamic, growth-generating change by participating in existing markets, producing existing goods and services, using existing techniques at lower prices. Schumpeter defines fives methods for creating dynamic change in markets: introducing a new good or service, or adding new features to an existing one, introducing new production technology or methods, opening new markets, and capturing new sources of raw materials or new methods of industrial organization (1934, p. 75). Competition in dynamic, free-enterprise societies is a process of change and creative destruction, with new combinations making previous ones obsolete (1942, 84). Dynamic competition often takes the form of product differentiation and bundling to compete *for* the market. Rivalry occurs among differentiated products; innovators and entrepreneurs change market definitions and boundaries by creating new products and services as well as new bundles of products and services. That dynamic discovery of new value propositions necessarily takes place in an experimentation process in which different producers interact, as do old and new combinations, to meet the market test of consumer value creation.

Schumpeter's disruptive innovator finds its complement in the activity of Kirzner's alert, aware, entrepreneur. The "entrepreneur-as-equilibrator" (2009, p. 147) uses *differential alertness* to profit, at least speculatively, from an existing opportunity to create net value. Differential alertness means awareness of and openness to a business opportunity that has not yet been widely noticed. This entrepreneur is not a Schumpeterian disruptive creator but engages in trial-and-error experimentation, playing a coordinating role by adapting to underlying changing conditions. Commercializing new products and service – as well as new bundles of products and services– is an example of "equilibrating entrepreneurship".

These ideas of entrepreneurship and experimentation are relevant to regulatory institutions and institutional change in electric power because decentralized coordination through market processes offers forward-looking coordination of future behavior that is not available to central authorities, including regulators. Markets offer agents of all types opportunities and incentives to make profitable discoveries through experimentation. Regulation as it is currently practiced does not. Regulatory institutions are based on equilibrium models grounded in static concepts of cost recovery that do not incorporate or allow for perceiving opportunities and making discoveries.

The technological and financial innovations described in Section II illustrate Schumpeterian and Kirznerian entrepreneurship through experimentation in the burgeoning residential solar market, and have created value for consumers and producers while meeting environmental policy objectives. The extent to which policies like net metering and a relatively technology-agnostic RPS enable decentralized market experimentation contributes to the innovation and growth in such a market.

IV. Conclusion

The case study presented above suggests that regulatory policies allowing for more producer and consumer experimentation enable social learning, and that market processes of trial and error give both buyers and sellers incentives to experiment, to create new and different value propositions, and to learn about how those different value propositions can be welfare enhancing. Given the array of federal and state policies, and that they are the combination of economic regulation and environmental regulation, in this complex policy context we are more likely at the margin to experience beneficial innovation where policies allow for experimentation on the part of both producers and consumers. In terms of economic regulation, this experimentation argument suggests that regulatory entry barriers in retail markets should be removed.

Renewable policies encompass the set of policies and programs enacted by state governments and often implemented through utility regulators to satisfy the state's environmental objectives. Examples of these policies include net metering, energy efficiency programs, and renewable portfolio standards. These policies are restrictive insofar as they impose particular service, investment, and/or pricing requirements on the regulated monopolist. Consider, however, an alternative approach to renewables and environmental regulations that is less restrictive in the sense that it does not rely on specific mandates or requirements. Instead, an un-restrictive policy might, for example, focus on removing existing entry barriers to all forms of renewables or energy efficiency technologies, and encourage market development for technologies that compete with traditional generation. The policy would, in other words, be technology agnostic, while relying on competition and changing technologies and business models to meet environmental demands.

Researchers, regulators, policymakers, and other stakeholders are in a unique position to contribute to future electricity market reforms by thinking not in terms of history or status quo, but by analyzing tabula rasa regulatory and policy arrangements critically. Like the Internet, the heart of a 21st- century electricity system is experimentation and innovation.

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Renewable Energy, Climate Change, and Entrepreneurship

Mark Hanson[1]

1. Introduction

In 2012 and 2013, Professor Warren Palmer invited me to speak at Beloit College on energy efficiency in buildings and payback analysis. The theme of both lectures was how our firm, Hoffman Planning, Design and Construction, Inc., that provides professional services in planning, design, and construction has been developing a process to design and construct highly sustainable or green commercial buildings at equal to or less than the cost of conventional commercial buildings. In the course of those lectures, I noted that in our experience conventional payback analysis did not seem useful when applied to green buildings. Payback analysis in the context of green commercial buildings was at best a limited tool, and at worst highly misleading. Frankly, traditional payback analysis was often getting in the way of our clients making wise choices in buying green commercial buildings.

When asked to participate in the 2014 Miller Upton Forum panel discussion on “Energy Efficiency, Climate Change, and Entrepreneurship”, I decided to revisit the subject of my previous talks and to reexamine Hoffman’s recent innovation in green building through the lens of entrepreneurship.

Previously, I had not even considered whether the commercial building design and construction services we were providing to clients would be categorized as entrepreneurial.

For the last fifteen years we have been striving to provide green buildings in all of our projects and to survive in a market place dominated by conventional

1 Mark Hanson is Director of Sustainable Services at Hoffman Planning, Design & Construction, Inc., Appleton, WI, and was Executive Director, Energy Center of Wisconsin 1994—2001

buildings. As a provider of green buildings, we focused on designing and constructing a product for our clients that lived up to our green claims and allowed us to stay profitable.

The nature of what is meant by a green building is rapidly evolving. The green building of the first decade of the 21st century emphasized energy and water efficiency, responsible materials and products, and good indoor air quality among other attributes. That view has rapidly expanded in the second decade of the 21st century to now encompass zero net energy, or at least zero net energy capability. A zero net energy building is one that produces as much energy on-site from renewable sources as it needs over the course of a year.[2] Such a building will typically import power from the grid at some times and export power at other times. An office building that uses less than 40 kBtu/square foot/year[3] is at the zero net energy capable threshold. Simply put, these buildings are highly energy efficient, and because they are so efficient, it becomes feasible for on-site renewable energy, usually solar photovoltaic, to supply much or all of their energy needs. Professor Warren Palmer's invitation to participate on this panel gave me reason to reflect further on what we had been doing at our firm since the turn of the century. That reflection was aided by the very helpful 2010-2011 *Annual Proceedings of the Wealth and Well-Being of Nations* recognizing the work of Miller Upton Scholar Israel Kirzner (Chamlee-Wright 2011). It led me to quickly realize that what we were doing in green buildings was an entrepreneurial activity as described by Kirzner. In the same publication, Dierdre McCloskey (2011) asks and answers a rhetorical question: "What works? Creativity. Innovation. Discovery." Our experience agrees with her answers.

2. Green Buildings at No Incremental Cost as a Form of Entrepreneurship

What we were doing in our firm's continuing innovation, testing, monitoring, and benchmarking of building construction cost, operating performance, and energy use was entrepreneurship. Our product was green. The types of commercial buildings we were designing and building included office buildings, med-

2 For an introduction to zero net energy buildings and their costs see the New Buildings Institute Research Report, Getting to Zero 2012 Status Update: A First Look at the costs and Features of Zero Energy Commercial Buildings, March 2012.

3 thousands of British Thermal Units per square foot per year

ical clinics, schools, retirement communities, religious facilities including monasteries, and some manufacturing buildings. These buildings cost our clients less than a conventional building both to purchase and operate. We were surviving and profitable as a firm during the last recession, a particularly difficult time for our industry. More importantly, we were not alone. Many other firms in various parts of the sprawling green building industry, including materials and building product suppliers, were also innovative and entrepreneurial, and together as a result we are rapidly transforming the nature of commercial buildings.

I want to draw a direct line between entrepreneurship and renewable energy and climate change. A green building (built green and performing green) provides superior indoor environmental quality and uses less electricity and natural gas than existing or conventional new buildings, and hence reduces greenhouse gas emissions in its operation. A substantially reduced level of energy use also enables on-site renewable energy to meet much or even all of the building's energy needs. Depending on the building size, design, and location, a zero net energy building is often now feasible from the standpoint of physics, and from the standpoint of economics.[4] The feasibility for a zero net energy building using on-site solar in terms of physics depends on the building's energy needs relative to the surface areas available, including roof area, parking lots, vertical surfaces, and finally land area for ground mounted solar systems. For high-rise buildings, net-zero on-site energy is not feasible. For many one, two, and even three story buildings, it is physically feasible. The argument for economic feasibility depends on whether on-site renewables can compete with energy from the utility company. The case for on-site renewable energy becomes particularly salient when a zero net energy building can be delivered in the market place for less than or equal to the first-cost for a conventional building.[5]

I can now confidently claim, based on our work and that of others in our industry, that a green zero net energy building can be delivered in 2015 at conventional first cost in some common situations. If this assertion holds, we can readily see why payback analysis does not work. The usual paradigm that we've had drilled into our psyche is that reducing or eliminating a commercial building's monthly energy bill requires additional investment, i.e. a higher first cost. Con-

4 A zero net energy building has a net-zero carbon footprint in its operation. The construction of a building has an unavoidable carbon footprint as it requires energy in the building materials and components as well as in the construction process including delivery of materials to a site.

5 First cost is defined as the total of all design and construction cost including site work.

ventional wisdom has been that a green building requires increased expenditures on insulation, windows, lighting, and mechanical systems compared to conventional commercial construction. In this traditional view, the building owner can pay back the added investment with the savings from the smaller energy bill in coming months and years, but the green building will still have a higher first cost. What I've just asserted, however, is that there need not be any additional up-front cost, and instead we have often seen a first cost reduction in our greenest buildings. Thus, the payback calculation yields a zero year or negative year payback.

3. The Impact of Carbon Pricing in the Commercial Building Market

Before considering some of the specifics of the entrepreneurial activity that is resulting in zero paybacks or less for green commercial buildings, it is useful to consider this experience in the context of Robert Stavins' work. One of Stavin's central themes at this year's Miller Upton Forum might be paraphrased with the broad statement "we've got to get energy prices right" if we hope to make fundamental changes in our patterns of energy use and carbon emissions. The price of energy must include the external costs caused by its carbon content. Stavins has noted policy challenges with respect to principal agent problems, spillover effects in research and development, and many other challenges that remain even if energy prices are right (Stavins 2015). The foremost challenge, however, is getting the cost of carbon into energy prices and making the discussion one of science and economics.

The USGBC (U.S. Green Building Council) notes that 40% of U.S. energy use is attributable to buildings, and that buildings are responsible for a proportionate share of the U.S. carbon footprint.[6] Given the magnitude of energy use and cost in commercial buildings (a subset of all buildings), it is important to ask: how much difference would getting energy prices right make to a commercial building buyer? Our clients occupy the buildings we build for them, and thus are not impeded by the principal-agent problem in leasing.

I'm going to draw on the example of a current client in considering how much their decisions might be altered by getting the price of carbon right. The

6 The U.S. Green Building Council Website www.usgbc.org provides a wealth of information on the built environment and green buildings.

client is in the early stages of making significant changes to four campuses. The client's current annual energy bill at these campuses (without any carbon cost in the pricing) is running in excess of $1 million per year or about $1.30 per square foot per year. These are energy costs at Midwestern utility rates, and thus may seem low to those from California or the Northeast. The total project cost is roughly $250 per square foot for the new facilities, not including deconstruction costs for some buildings that no longer meet the client's needs. In addition to updating their campuses to better serve their needs, a goal of the client is to decrease its operating costs per square foot for energy at current utility rates.

What impact would higher energy prices that priced in carbon have on the client's decision-making for improving its campuses? As we have estimated the carbon footprint for this client, we can adjust their current energy bill for a given cost of carbon to gain some perspective of how large carbon pricing looms in this context.[7] Using what some would consider a high cost of $50 per ton of CO_2, the annual energy operating cost of the existing facilities would rise from $1.26 per square foot to $1.85 per square foot. Because of the efficiency levels designed for the client's new buildings and improvements in its existing facilities, the estimated annual cost of operating the revised campuses is estimated to be $1.60 per square foot if a cost of $50 per ton of CO_2 were included in their energy prices.

While energy operating costs are important information for the client, the magnitude of the new construction cost per square foot ($250) suggests that a $0.59 per square foot increase in annual operating costs due to a CO_2 price of $50/ton is not likely to be a dominant factor in the client's new construction decisions. In other words, how much impact does adding $375,000 per year in energy operating cost due to carbon cost have on an $80 million project? This client, typical of our other clients, has multiple building goals in providing spaces that meet various functional needs, comfort, indoor air quality, daylight and views, occupant control, and ease of maintenance to name a few.

What insights can be drawn from this example client and the prospective inclusion of carbon pricing? I suggest there are three main conclusions:

A commercial building purchase is a complex decision with many factors to be considered; energy cost, with or without carbon cost included, is just one of many considerations, and for most purchasers, energy operating costs are not the

7 The carbon footprint is estimated based on the client's utility bills and using the U.S. EPA Portfolio Manager.

most important consideration.

Including the cost of carbon in energy operating costs will increase the importance of energy efficiency; however, given the relatively modest size of energy costs in the context of the many considerations in the building decisions, including carbon cost is unlikely to transform energy costs into a dominant consideration.

However, including the cost of carbon in considerations of on-site renewable energy is an important change. Energy costs in the Midwest are currently at the point where over a 25 year horizon, purchasing electric power versus generating on-site solar electric power have about the same cost. We have started offering on-site solar options, and some of our clients are choosing on-site solar if the cost is about equal. Some prefer solar even if the price is marginally higher. Including $50 per ton of carbon in the price of utility-supplied power, equal to $0.05 per kWh, is a game changer since on-site solar would clearly reduce our clients' electricity costs while achieving their green goals.

4. Entrepreneurship in Green Commercial Buildings in the Absence of Carbon Pricing

As we have not yet included carbon cost in our energy pricing, let us return to the development of green zero net energy buildings at no added cost relative to conventional commercial buildings as an entrepreneurial activity. The competitive advantage for a firm such as ours is that buyers should prefer a zero net energy building even at today's energy costs. While energy costs may not be the highest priority for the building purchaser, the opportunity to avoid some or all energy operating costs is still a motivating factor in the building decision. Thus, buildings approaching or reaching zero net energy represent significant progress from design, construction, and competitive perspectives even in the absence of getting energy prices right.

I want to briefly note six milestone events in the timeline of our firm's entrepreneurial efforts that brought us to this point and provide a couple of building examples. The first event occurred in 1999 following our firm's decision to move in a consciously green direction. The first milestone was our construction of our own office building that incorporated a green design approach emphasizing daylighting. Design principles were guided by the Daylighting Program at the Energy Center of Wisconsin which was based in part on the work of Ternoey (1985). We wanted to design, build with our standard integrated construction management approach, and then live with the new design. An important outcome of our experiment was that the total building cost came in below average for similar office buildings in the area. The building proved to be well accepted by employees and visitors, and provided a living laboratory for our employees to understand the design, construction, and operation of our emerging business approach.

Using the lessons learned in our own office building, we began to incorporate similar design changes in most of our projects, including new public schools and a large government administrative building. The second milestone event occurred in 2002. We had designed and built over twenty blood clinics for a pharmaceutical client. With a new round of clinics on order, we decided to deliberately green the design with what we call an integrated sustainable design approach. The great fear in our company was that by greening the buildings we would price ourselves out of competition. While some of us leading the change had fairly solid evidence from our experience and experience of others that we could control cost, some of our architects and construction managers were skeptical. Thus, we were encouraged when the final costs came in on the first "green" blood clinic. The total project cost had declined by over 2 percent. This very significant outcome provided a highly visible example that green buildings made competitive sense.

One of the challenges in commercial building research is that it is very difficult to apply scientific control to innovation because of the complexity of the product. It is too costly to build a commercial building as a scientific control and then build alternate versions of the building for testing purposes. Some firms, such as MacDonald's and Wal-Mart do repeat standard designs. Even in these exceptional cases, construction costs vary from location to location, and there is limited interest in testing. We were fortunate to almost have a controlled study when building the first "green" blood clinic since just the year before, we had built a conventional blood clinic for the same client under similar cost conditions.

The third milestone on this path of "creativity, innovation, and discovery" was our participation in the design and construction of the Alberici headquarters in St. Louis, completed in 2004. Alberici was seeking a high LEED® certification on a conventional cost budget, so this project provided an entrepreneurial opportunity to apply our design principles on a larger scale project. We were brought into the project at the mid-point in the design process after initial construction cost estimates had been prepared. As Alberici is a construction contractor and was building the facility for itself, we could then apply our set of developing design features and observe the impact on the project cost estimates, the anticipated energy use of the project, and the estimated LEED rating. The results suggested that we could reduce the project cost by $2.5 million, increase the LEED rating to Platinum, and reduce energy use. Alberici headquarters was ultimately certified at LEED NC v2 platinum and for a period of years held the highest LEED new construction certification rating. We have also been able to observe employees' reactions to working in this facility and the building's energy and water use. Information on other LEED platinum buildings revealed that the Alberici was one of the lowest cost LEED Platinum buildings and that its per-square-foot cost was very competitive with conventional buildings in the St. Louis area. (Hanson et. al. 2006) With this milestone, we were confident in the integrated sustainable design approach we were applying in our projects. By this time, we were committed to applying our green approach to all of our projects.

The fourth milestone was the application of our full integrated project delivery approach to the design and construction management of two public school projects in Wisconsin. The challenge and opportunity was to earn high LEED certification ratings in a context where both school districts had set budgets based on preliminary designs and conventional cost estimates for those designs prior to hiring our firm.. Upon completion, both schools achieved LEED Gold Certifications, among the first schools in the country to receive that recognition. Moreover, the schools' construction costs were 25-29% below the regional average for new school construction. These two schools showed the importance of sustainability in the competition for the work.

Our firm's fifth milestone was the design of Holy Wisdom Monastery, a 34,000 square foot building with meeting, office, library, and dining facilities. Monastery leaders were committed to the construction of a highly green facility. In our mind, this implied a building with a very low energy requirement capable of meeting its energy needs with on-site renewable energy. Holy Wisdom Monastery was completed in 2009 with a 20 kW solar system at a construction cost of $209 per square foot and a total project cost, including design fees and the pipe organ expansion, of $246 per square foot. The monastery received a LEED platinum certification. With solar PV costs in 2009 at $7.90 per installed Watt, it was not financially feasible to provide for more than about 10% of the energy requirement with solar. But the energy requirement of 32.9 KBtu/sf/yr is within the range of what is considered to be a zero net energy capable building, the owner's ultimate goal for their facility. (Hanson 2011)

For that segment of building owners interested in sustainable facilities, a zero net energy building is the grand prize, one that is financially attractive to any owner if it could be provided at conventional cost. Our entrepreneurial activity led us to recognize the competitive and environmental potential of zero net energy buildings. Another indication that the market place is heading in this direction is The American Institute of Architects' support of the 2030 Challenge that sets a sequence of aggressive goals leading to carbon neutrality for all new construction by the year 2030.

The sixth milestone occurred in 2014 with the addition of 126 kW of solar PV at Holy Wisdom Monastery. The new installation with the existing 20 kW system now supplies almost 60% of the monastery's energy needs. Third party investors enabled the monastery to add the new solar system with minimal up-front investment. The monastery will essentially pay on a monthly basis the same cost for the solar electricity as they would have paid to the electric utility for green power, and slightly more than if it purchased fossil-based power. System ownership transfer will occur in year 15 with the monastery paying residual value at about 25% of the original system cost. Were it not for state limitations on interconnection capacity and the buy-back rates on power sold to the grid, the system could have readily been expanded to net-zero or carbon neutrality.

The issue of what is appropriate cost allocation for grid interconnection for on-site solar is currently a hotly contested topic. What this milestone solar system with third party financing demonstrated in combination with the previous milestone, however, is that a highly green building can be delivered at this time at a first cost very competitive with conventional buildings. Furthermore, the building has a low energy demand and provides 60% of that requirement with on-site renewables.

When we set out on our entrepreneurial path, we did not foresee our current ability to supply zero net energy buildings at equal to or less than conventional cost. As Kirzner says (2011:27), "the availability of pure profit opportunities which, in ways we admittedly do not fully understand, attract entrepreneurial attention." As we included higher cost elements in our commercial building designs, we found ways to reduce costs of other components with the net effect of maintaining or reducing overall project cost as we built greener buildings. As a result, we increased our firm's revenue and profitability as we emerged from the last recession. Our abilities in integrated sustainable design combined with our construction management process provide more competitive pricing and greener buildings.

Hawken et al (1999) named this phenomenon "tunneling through the cost barrier": innovation that simultaneously reduces first cost and annual operating costs in green design and construction. The first time I heard of this concept twenty years ago, I thought it sounded great in theory, but what did it mean in practice? I could not come up with tangible examples at the time. Recently though, we have discovered how to tunnel through the cost barrier by reducing the number of light fixtures while using better fixtures and lamps; choosing windows that controlled unwanted heat gain and managed glare while reducing the need for solar shading devices; managing plug loads; downsizing HVAC systems; and using innovative financial arrangements for on-site solar. In the designs that emerge in this process, some building elements may cost more (say LED lights or a heat pump mechanical system), while others cost less (fewer solar shading devices and fewer light fixtures). But overall, aggregate first cost can be reduced as sustainable design also reduces annual operating costs, as shown by Holy Wisdom Monastery.

The construction cost of Holy Wisdom Monastery can be compared to a set of sixty buildings, approximately half of these were LEED certified at various levels but none at platinum and the other half not certified. These buildings were academic buildings with a similar mix of rooms to those found in the monastery building and are reported in a study by Davis Langdon an international construction management firm (Morris and Matthiessen 2007). As these buildings located on campuses are scattered across the U.S. and built in different years, the study controls cost for location and year. There is no discernible difference in the cost of the LEED certified buildings and the non-certified buildings. The reported construction cost ranges from somewhat over $200 per square foot to almost $600 per square foot. Holy Wisdom Monastery construction cost adjusted for year and location comes in at approximately $230 per square foot, at the very bottom of the cost range. This demonstrates viability of our entrepreneurial approach to a zero net energy sustainable building.

5. Lessons and Implications of Entrepreneurial Activity

One might think that the example of Holy Wisdom Monastery would make future marketing and sales of our green building services a slam dunk. We certainly use this and other examples in our business development, and they are helpful. Buyers in the marketplace, however, often have reservations. Working with hesitant building buyers is not unique to us, as I have heard similar comments from other firms offering similar levels of green buildings at similar price points. One explanation for the hesitancy of building buyers might be that the concepts of marginal cost curves and payback analysis for added efficiency or renewable investments are so ingrained in the market place that potential buyers cannot fathom the notion of tunneling through the cost barrier. And even if one project managed the tunneling, can the next buyer of say a $10, $20, or $30 million building (the mid-price range for our projects) be confident that the process is reproducible for their project? Buyers have a tendency to focus on single project elements (LED lights for example) and want to think in terms of paybacks on each building element rather than looking at the aggregate project costs before and after the tunneling. Hence, my comment at the beginning that payback analysis sometimes gets in the way. And in our buyers' defense, most of them are not routinely making $20 million purchases.

Our experience with entrepreneurship in green buildings is emblematic of the larger trends that I believe are common in the commercial building industry. The materials, MEP (mechanical, electrical, and plumbing) systems, windows including emerging smart windows, the emergence of smart building control system, are all evolving rapidly. Fluorescent lighting is giving way to even more efficient LED lighting before our eyes. Other highly sustainable, zero net energy buildings with good cost points are appearing on the landscape, such as the Iowa Utility Board's new office building in Des Moines or the Bullitt Foundation Headquarters in Seattle. It is this rapidly evolving entrepreneurial action that offers significant prospect for pulling down, to use Paul Hawken's phrase, CO_2 emissions from new commercial buildings and in retrofitting existing buildings.

What these entrepreneurial paths need for widespread use of on-site solar and other renewables in green buildings, however, is the adoption of smart grids and smart building controls so that we can more readily use energy price signals to enable the use of on-site and off-site renewable energy, optimize power generation and transmission, and provide incentives for energy storage. Including the cost of carbon emissions in the market place would obviously be helpful in accelerating the market for low carbon and zero net energy buildings. Energy operating costs are not so high as to be among the highest priorities in commercial building design for most building buyers. Including the cost of carbon, would increase the importance of energy performance. As I have argued, including carbon costs could be decisive in tipping more owners into including on-site solar. Without regulatory changes and investments in smart grids, we will continue, even when carbon pricing arrives, to bump up against the limits we currently face in Wisconsin that prevented Holy Wisdom Monastery from moving to full zero net energy.

I hope my remarks have offered some perspective on how entrepreneurial activity is driving the green building movement. If we can provide zero net energy buildings at the same first cost as conventional buildings with the tools and methods we have in hand today, there is opportunity and some hope looking forward as we take up the challenges of climate change.

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Using Tax Financing Strategies to Help Fund a Zero Net Energy Landmark Building and "Green" Endowment for Beloit College

By: John Clancy[1]

Beloit College is actively planning "to convert the Blackhawk Generating Station, a river-front, decommissioned 100-year-old coal burning power plant, into a student union and recreation center – The Powerhouse." (Schoof 2015)

The College engaged Chicago-based firms Studio Gang Architects and dbHMS Engineering to design a renovation that creates a modern combined recreation, student center while both preserving the historical character of the building and advancing the College's ambitious sustainability goals.

Studio Gang Architects and dbHMS Engineering have proposed a unique geothermal heating and cooling system for the $38 million, 130,000 sq. ft. project. "Their idea is to create an active, isothermal skin for the building by wrapping the exterior with polyethylene tubing, adding a significant insulating envelope, and covering it all with weathering steel. Through the tubing will flow liquid that uses the moderating temperature of the river water to turn the massive masonry walls of the facility into radiant surfaces that will heat and cool the building, keeping it a constant temperature throughout the year." (Schoof 2015) The design preserves the historical interior of the building, maximizing interior space, while potentially reducing initial renovation costs and decreasing future operating costs.

If completed, the proposed design would give the College a landmark, na-

1 John Clancy is an environmental and energy lawyer at Godfrey & Kahn. While this article generally discusses tax and related legal issues, it is not intended to provide legal advice for any particular situation. If the College or anyone else pursues an energy project utilizing any tax financing strategies, it is very important that they have their own legal advice to address the various issues that apply to the project.

tionally unique building on the cutting-edge of sustainable design.

As this paper shows, the College could take this project one step further by making the renovated building zero net energy through the installation of large-scale solar photovoltaic (PV) facilities on or near the Powerhouse. A zero net energy building produces as much energy on-site as it consumes in a year.

The resulting 130,000 sq. ft. structure would be one of the nation's largest, commercial zero net energy buildings.[2] The completed renovation would not only provide the College with much needed functional space, but also with a cornucopia of publicity for years to come.

In 2012, Oberlin College had a 2.278 MW PV system installed on its campus without paying for the project upfront. Spear Point Energy, the project developer and system owner, coordinated the design and engineering of the project and "negotiated the Power Purchase Agreement and Lease needed to make the system a reality." (Spear Point Energy 2015) The agreement provided Oberlin College with renewable electricity at a competitive, guaranteed rate for 25 years while the 10 acre PV installation also provided a highly visible marker of Oberlin College's commitment to sustainability. As a private firm, Spear Point Energy was able to receive tax-based solar incentives unavailable to non-profit Oberlin College if it had built and owned the system itself.

A similar PV system installed on and around the Powerhouse would raise the College's sustainability successes to a new height. The problem for Beloit College, and the State of Wisconsin, is that power purchase agreements, such as Oberlin College used to site a large PV facility on its campus, are much more challenging in Wisconsin. However, as this paper will show, alternative financing and ownership mechanisms can be used, and have been used, in Wisconsin that achieve the financial benefits of a power purchase agreement. At low upfront cost, Beloit College could install a PV system able to produce renewable, solar energy equal to the Powerhouse's annual energy demand, making it a zero net energy building.

This essay discusses potential methods for the College to take advantage of the significant tax advantages available for solar PV systems, even though the College is not a taxable entity. It will also discuss strategies to fund the solar project, make the Powerhouse a unique zero net energy building, and create a stable and self-sustaining "green" endowment for the College.

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2 *Currently, the largest net zero building in the U.S. is The Research Support Facility at the National Renewable Energy Laboratory in Colorado.*

1. Beloit College's Strong Sustainability Goals and the "True Cost" of the Energy it Uses.

The College has a strong commitment to sustainability, both in its academic activities and with respect to its physical plant. This is reflected in both the many actions taken by the College and in the leadership of Beloit College's President Scott Bierman, who has said[3]:

"I strongly support the current and future sustainable activities on campus. I believe that there are both economic and educational reasons for enhancing efforts to identify sustainability projects. Of particular interest are projects that meet reasonable cost-benefit tests; curricular opportunities that introduce environmental issues into courses in a variety of disciplines; and research projects that expand our understanding of the complex interplay between environmental systems and environmental policy."

One of the key reasons for installing relatively large-scale solar PV systems and utilizing their energy is to allow the College to meet its sustainability goals and reduce its environmental footprint. Presently, Beloit College, like almost everyone else in its area, purchases energy from its local utility provider. As is common in the Midwest, the majority of electrical energy that the College's utility provides is produced by coal-fired plants. Coal-fired plants emit, on average, about a ton of carbon dioxide per megawatt hour, or about two pounds per kilowatt hour. That emission rate and an estimated damage value of $30/ton of CO_2 equivalents "results in climate related damages that equal about 3 cents per kilowatt hour," which "is in addition to the 3.2 cents per kilowatt hour that are estimated for non-climate damages." (National Research Council 2009) In contrast, the operation of solar energy PV facilities produces neither CO_2 nor other potentially harmful air emissions.

2. The College's Catch-22.

Because of the College's strong sustainability goal and its plans for a green renovation of the Powerhouse, it would likely greatly benefit from being able to use on-site solar power to provide energy to the Powerhouse and other Beloit College buildings. Fortunately, solar PV systems have come down substantially in

3 *See http://www.beloit.edu/sustainability/assets/Beloit_campus_sust_map_color_2.pdf.*

price over the past several years. In addition, solar PV systems are eligible for significant federal tax incentives that can substantially lower the net cost of installing such systems.

Moreover, as noted above, Beloit College has strong sustainability goals. For this reason, Beloit College and other environmentally-conscious, not-for-profit organizations are often among those most interested in installing solar and other clean energy systems. However, because they are non-taxable entities, they cannot directly receive the significant federal tax benefits available for solar and other renewable energy projects. Hence, the Catch-22: those often most interested in solar and other renewable power cannot directly receive the most significant Federal incentives to develop that power.

3. The Basics of the Federal Tax Incentives and Structures that Can Help Solve Beloit College's Catch-22.

The Federal tax incentives for solar PV installations include a 30% investment tax credit that is available for systems that are installed and operating before the end of 2016. This tax credit is available to directly offset Federal tax liability, and therefore can have significant value to taxable entities. In addition, the tax credit is generally available for the entire cost of the solar facility. Thus, a $100,000 solar facility will generate a $30,000 investment tax credit. In addition to the tax credit, the cost of solar facilities can often be depreciated over a short seven year timeframe, and thereby provide substantial tax deductions. Taxable entities that receive the 30% investment tax credit receive a 15% reduction basis for depreciation purposes. However, because of the relatively short depreciation schedule, depreciation deductions associated with solar facilities are also quite valuable to taxable entities.

Fortunately for Beloit College, there are legal structures that can help nonprofits and other nontaxable entities to address their Catch-22 and receive value for the significant tax incentives for solar facilities. One of the most commonly utilized structures is generally referred to as the "partnership flip." The partnership flip allows for a nonprofit such as Beloit College to enter into a partnership arrangement, often through a limited liability company (an "LLC"), with a taxable investor.

Under the "flip" structure, the nontaxable entity initially is typically provided a minority ownership interest in the LLC for tax purposes. The taxable investor, on the other hand, typically has a majority ownership interest for tax purposes. This allows the taxable investor to receive most of the tax benefits available for solar projects. The LLC typically will enter into an agreement under which it provides energy to the nonprofit. The U.S. Treasury Department allows for a "flip" of ownership without there being a recognized taxable event. This flip could allow for the College's ownership to be almost 100 percent. The College could then purchase the remainder of the taxable investor's ownership interest at its then fair market value.

Although the partnership flip option is often used to transfer ownership without a taxable event, a variation of this arrangement is often used with nontaxable entities, since their involvement in a partnership flip could limit the ability of the taxable investor to take advantage of the accelerated seven-year depreciation schedule. Under this variation (the "LLC Approach"), instead of the "flip," the investor receives a "put" right to sell its interests in the LLC for a relatively low amount after it has received its needed return. As backup protection for the non-taxable entity, there can be an opportunity for it to purchase the taxable investor's interest in the LLC and/or the solar facility for its then fair market value.

4. Solar Payback with and without Tax Incentives.

As one might guess, solar tax incentives make a big difference with respect to the net cost of the solar facility and payback. One can see this by comparing the payback of a potential solar facility for the Powerhouse with and without tax incentives.

In determining the solar facility's payback, it is important to know the rate that the College pays for its electricity, since that determines the value to the College of the energy produced by the solar facility. Beloit College has a somewhat unique arrangement with its utility provider, under which it can purchase energy for its entire campus as if it were one building. This allows the College to aggregate its energy usage under a large customer commercial rate, and to purchase energy at a relatively low marginal cost of approximately 6.8 cents per kilowatt hour during on-peak time periods (which are generally daytime hours on weekdays). In return, the College must pay a demand charge, which is based on its peak energy usage during on-peak time periods throughout the year. This provides incentives for the College to manage its load to avoid on-peak spikes in energy usage, and thereby help the utility's overall energy profile.

While Beloit College's marginal cost of utility supplied energy is relatively low, the "true" cost of Beloit's energy usage, at least from an environmental prospective, is substantially higher. The true cost for electricity produced by coal-fired facilities is approximately 14 cents per kilowatt hour (6.8 cents plus 3 cents from CO_2 emissions and 3.2 cents from other emissions as discussed above).

Based on Beloit College's present energy usage, even without any additional energy demands from the Powerhouse, the College could likely support a 2.8 megawatt solar facility. Such a system might cost about $6.25 million to install. Assuming that the College could offset energy at an average rate of about 6 cents per kilowatt hour, such a system would likely result in in energy savings starting at $190,000 per year and increasing thereafter based on the inflation rate for electrical energy. It is reasonable to assume an offsetting rate of 6 cents per kilowatt hour, since a portion of the energy the solar facility produces will offset lower-cost, off peak energy. If the College was unable to receive value from the investment tax credit or depreciation available for solar PV systems, the system would have a relatively long payback period of about 24.3 years, and a relatively low internal rate of return of 1.7% over 30 years.

It is important to note, however, that the solar facility payback would be substantially shorter if Beloit College's true cost of energy were considered. For example, even if one assumed that only half of the energy provided to the College was coal fired and the other half had no emission concerns, the "true" cost of the energy offset by the solar facility would likely be over 9 cents per kilowatt hour (6 cents, plus half of 6.2 cents for environmental costs). This likely understates the true cost because coal produces more than one half of Wisconsin's energy and other energy sources, such as natural gas also have CO_2 and other emissions. But if the true cost is assumed to be 9 cents, the "payback" for the solar facility would be reduced to about 16 years, and the internal rate of return increased to 5.2%.

If the project was implemented using the LLC Approach described above, the benefits to the College from the investment tax credit and accelerated depreciation would depend upon the particular terms agreed to between the tax investor and the College. However, based upon a general range of investment terms likely required by investors, the payback would be reduced from over 24 years to somewhere between 16 and 19 years, and the internal rate of return over 30 years would likely be improved to between 4% and 5.3%.

5. Use of "Zero Energy" and Tax Advantages to Help Fund Raise for Powerhouse and to Create "Green" Endowment.

Making the historic Powerhouse into one of the largest zero net energy buildings in the world could likely enhance the College's fund raising efforts for this unique facility. Moreover, doing so could allow the College to create a "green" endowment to provide a steady, substantial, and likely increasing source of funding to help meet its operational expenses.

This green endowment would be substantially more valuable if the College utilized the LLC structure for the solar project to enhance its return. In particular, if the College were able to fund raise for a substantial portion of the $6.25 million installed cost of the 2.8 megawatt system, it could likely use the LLC Approach to allow it to only pay a very reduced cost for energy for 6 years, and then receive full ownership of the system and save approximately $220,000 per year in energy costs from that point forward. For example, the College could seek donations from its alumni and others to fund its $4 million contribution toward the cost of the system and to make the Powerhouse a zero net energy building. The College could then negotiate to receive full credit for that contribution to the solar LLC, and potentially enter into an agreement where it pays only about 2 cents per kilowatt hour for approximately 6 years, and then purchases the tax investors' interest for about $190,000. During this initial time frame, the College would receive savings from the solar powered energy beginning at about $125,000 per year. After the buyout, the College would own the system outright, and receive from it a steady and generally increasing source of funds from the solar facility. Based on the College's present energy costs and assuming a relatively low energy inflation rate of 3%, the "income" from the solar facility would start at $220,000 per year and generally increase thereafter.

It is important to note that by the time the College owns the solar facility outright, the cost of carbon for coal fired energy may have become internalized because of EPA's proposed Clean Power Plan, which is to be finalized in June of 2015. This Federal rule will require coal-fired units to substantially lower their carbon emissions in the future, and will likely require utilities to buy offsets if their coal-fired units cannot meet these stringent targets. Indeed, the College may actually be able to receive significant payments for producing and using this green energy from utilities that need to offset their coal-fired carbon emissions. Therefore, the savings to the College after year six from using clean solar energy may be substantially greater than $220,000 per year, making the "green" endowment even more valuable.

Thus, with the help of solar tax incentives, the College could both transform the Powerhouse into a showcase zero net energy facility and create a "green" endowment. By creating one of the nation's largest zero net energy, repurposed buildings, the College would become a world leader in sustainability. In addition, the "green" endowment could provide an immediate return of approximately $125,000 per year and after 6 years an increasing annual payout that begins at about $220,000. Since many colleges and other non-profits find that it is easier to fund raise for "cool" capital projects than on-going operating costs, this strategy could provide the College with a unique opportunity to have its cake and eat it too, by allowing it to both create a truly word-class green building and a permanent endowment to help offset its future operational costs.

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Renewable Energy, Climate Change, and Entrepreneurship

John Nelson[1]

I'm representing the entrepreneur element of this panel discussion on "Renewable Energy, Climate Change and Entrepreneurship". Our company, Global Asset Infrastructure, LLC, raises capital in the private markets and deploys it in infrastructure projects. Our firm combines a commitment to long-term returns with meeting the world's accelerating needs for energy, water, waste treatment, and other forms of infrastructure.

Our firm's commitment matches my own values and experience. I've watched broad secular wealth creation for 40+ years. The use of fossil fuels has contributed materially to this wealth creation, notwithstanding the climate consequences we are here to explore.

And I've watched with increasing frustration how environmentalism has become stuck in '60's era radical opposition/advocacy/hypocrisy/irrelevance. The inability for any discussion of nuclear generated electricity, the universal opposition to fracking, divestment/350.org – all seasoned with highly emotional but not especially holistic/system level arguments and hard choices – are examples. I remember the nuclear moratorium in response to the greatly exaggerated incident at Three Mile Island – resulting ironically in the acceleration of carbon-intensive, base-load, coal-powered electricity in the U.S. and in other countries.

I believe that broad wealth creation is essential to the improvement of the human condition, especially for those whose needs are not met on a daily basis.

I also believe that environmental stewardship – especially like that of Aldo Leopold – is also essential, and is one of the most tangible ways that I can express my values. In the Anthropocene, human transactions with nature need to shift

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from vertical (with humans on top) to horizontal (more in balance).

This friction/opposition between capitalism and environmentalism provides enormous opportunity. Our firm pursues wealth creation through funding infrastructure investments that stress the importance of environmental stewardship. We might be the vehicle that would fund the solar PV project discussed by the previous speaker, John Clancy. But, I'd first like to take a step back, to talk about first principles and about our ideas for environmental stewardship in the marketplace.

The way entrepreneurs succeed in the marketplace is by recognizing a future need, getting ahead of that need, and positioning themselves to solve a problem before the market really knows it needs solving. Then, the market comes to them for the solution. My greatest accomplishments have come from taking risks, by moving disruptively ahead of current thinking and waiting for the market to "come to me".

How do humans currently conduct their business with nature? Right now, the transactions between humanity and nature occur principally in a vertical manner, where people either extract or puts something back in nature for economic benefit. As John pointed out, now we only price the economic benefit to us. We don't price the cost to nature, such as the externalities in the production of electricity.

From a very fundamental perspective, we're now in the Anthropocene. We believe at Global Infrastructure Asset Management that the human-nature transaction has to change from vertical to more horizontal, that the relationship between humanity and nature has to become more balanced. We are betting that if we figure out how to do that in economic terms, we will be ahead of the competition.

Every research project needs to begin with asking the right research question, so what's the research question? I'm about to commit heresy in a group of economists, but you invited me here, so here we go.

At first principles, is climate change an economic problem that can be solved simply by financial means? Or at first principles, is this a physics problem that no amount of money alone can solve: this matter of energy, climate, and the coupling of the two?

Warren expressed it elegantly at the beginning when he remarked on how many people benefit from burning fossil fuels. This isn't one of those either-or choices. It's not like smoking where if you quit, your health gets better and you spend less money. This is a hard choice where we have to strike a balance.

Is it a financial problem at first principles? Is it a physics problem? Or is it both? Our premise is it's both. You have to strike the balance in financial and natural terms. So this is our business premise and our investment premise, and it permeates everything we do.

We seek to find this balance between these two poles, one of which is financial motivation and the other of which is environmental or natural motivation on the fulcrum around social capital and infrastructure in the context of improving human capital.

Striking the balance is the key for us as entrepreneurs, and for how we deploy our capital (which is often your money one way or the other). I will take one exception with John's reference to "free money that came from the government". It's not really free. Somebody ultimately provided that money. The money that we spend is our money. It's your money. It's foundation, endowment money. Interestingly enough, when it turns out to be your money, you get very interested in the rate of financial return on it, particularly when it involves your retirement.

We strike this balance with a keen eye on fair financial return, but also on doing the right thing with natural capital. I'll come back to natural capital in just a minute. But in the interest of getting to the end and then coming back and repeating it, I'm just going to give the headlines of what this leads to.

First: all renewable energy is solar based. I find it interesting when I hear people say, "Solar, hydro and wind." Hydro and wind are just conveyance mechanisms for solar energy.

While all renewable energy on the planet is solar based; it's not all the same. There are some forms of renewable energy that better strike the financial-environmental balance. I make 60% of the electricity my home uses with solar PV, but our firm would probably not invest in John's project because it is, in our opinion, over "financialized".

He described a solar PV project that is very complicated from a financial perspective. It relies on resiliency of financial predictability that you can't really build a business around. We had an election yesterday and all of those things that John's structure relies on could go away. We're building businesses that need to be able to be replicated over a long period of time.

Some types of ventures strike the financial-environmental balance very well. Hydro strikes the balance well. Solar hot water heating on your house strikes the balance really well. Wind almost strikes the balance well. Some don't. Notwithstanding how much solar PV has come down in price, the tax equity financing that John discussed is over "financialized".

Others are proxies for another problem. We talk a lot in Wisconsin about biodigestors, digestate, biomass, and using photosynthesis to produce renewable energy. Well, photosynthesis does a very good job of creating mass. It does not do a very good job of creating energy.

When we start to expect mass to make energy, we have unintended secondary consequences. Food for energy is an example of an unintended secondary consequence. Digesters, considered in broader terms, make renewable energy - but, in reality, their primary role is habitat protection at first principles.

Now I'm going to go back to Hawken's and Lovins' "Natural Capitalism." There are four endowments: habitat, energy, potable water, and atmosphere. Those are singularities. We only have one of each. We only have one endowment of fossil fuels. We only have one endowment of potable water. We only have one endowment of atmosphere. Once those things are depleted or exploited, we don't have a reset button to hit to replenish them.

From an investment perspective, we look for projects or companies that have some value connection back to more than one of these endowments. For example, a manure digester takes contaminants off the land, concentrates them, and puts them in a place we might make better use of them, maybe in the form of a fertilizer. A digester also makes a little bit of energy.

Maybe by not putting manure on the land, we make the water cleaner, or we make the drinkable water cleaner in that land area. With respect to atmosphere, I'm not so sure. Most of the digesters in Wisconsin or in the upper Midwest use a lot of diesel fuel hauling liquid manure around. And I think if prices weren't so skewed to reward renewable energy with cheap diesel fuel to haul around the material that makes the renewable energy - if that flipped around, I'm not so sure digesters would do so well economically.

But, the point here is that a digester is more about habitat protection with some incidental energy benefit and some incidental potable water benefit. And the problem is we can't financialize all of the benefits produced by the digester. We can't get paid for producing those benefits right now.

So when we look at projects, we look through this screen of balance and the four singular endowments, and try to find projects that strike the right financial-environmental balance.

I've been designing and building infrastructure for more than 40 years, specifically venture capital or capital placement advising for about ten years. Here are a few more "ahas".

Scale really matters. Right now, the best opportunities are small- to mid-scale, not mega-scale. The mega-scale is too much money chasing bad ideas. Anybody who invested in a green fund in '08 or '09, has seen their investment decline pretty precipitously. There's too much money chasing these mega-scale ideas.

That's unfortunate because the climate change problem articulated is at-scale with urgency. The scale that we're able to work at right now is too small to solve the problem on the necessary timeline. But, things change. Just look at how technology has evolved.

The other thing I will say is that we do not finacialize policy. We treat government tax benefits as frosting on the cake. We need to strike the balance at first principles and convince ourselves the investment is a good idea - that we're going to spend your money or our money on something that's a good idea. And if there are policy incentives that have come along on top of it, great. That makes it a better idea.

But I'm old enough now to have lived through the Carter administration, syn fuels, Reagan and others. I have personally had financial setbacks from relying on policy resiliency in the United States. So our firm will take advantage of subsidies, but our initial screens do not have any policy advantage in them.

And finally, in this business there are no economic windfalls. This is not medicine. This is not digital technology. It's not software. There are no home runs. This takes patient capital invested over a long period of time with fair, but modest, returns. If someone represents this type of investing as having home runs, then there must be something wrong with their physics, in my opinion.

Last, but not least, is an example of one of the things we own and we really like -- small-scale hydroelectric generation.

Before rural electrification, there were many small dams built in the upper Midwest, actually in the developed world at this latitude, that were used to power mills, to power plants. Some of these were built by Henry Ford.

While you may say that building a dam has negative environmental consequences, we all have negative environmental consequences when we swing our feet out of bed and step on the ground every day. Nothing is absolutely clean.

These dams are here. We're starting with them in their current condition. We're able to use technology and improve the output of these old dams that have been in place for 100 years by maybe a factor of two or three. And this is pure green energy.

Anybody ever heard of EROI, energy return on investment, or the second law of thermodynamics? Hydro is the winner for that calculus.

If you come to me and say, "This is my retirement funds or my savings so my children can go to college. I want to put it in renewable energy and I want to do the best I can with it financially," this is an example of where we would aim first, at small-scale hydro.

In summary, I think climate change is not just a financial problem. I think it's a first principles natural and financial problem that needs to be balanced. I think we need to use the five capitals, natural capital, and financial capital with social capital, human capital and manufactured capital, infrastructure such as we build, all in play. And I think we need to protect the four singular endowments.

As we get this figured out, I think we wind up in a spot ahead of where the market is now because the market doesn't think in those terms.

Addressing Climate Change Should Boost the Economy

John Norquist[1]

Thank you to the organizers of the Upton Forum for the opportunity to speak. I offer special thanks and greetings to my long time friend Professor Jeff Adams. I will talk about climate change and how it relates to energy, buildings and cities

From recent discussions, it seems the UN and the political leadership of most advanced wealthy democracies, including President Obama, would like to view climate change as they viewed the threat to the ozone layer caused by widespread use of chlorofluorocarbons (CFCs). The solution of the ozone threat was almost purely regulatory. Worldwide cooperation to halt use of CFCs saved us from an existential threat. There was some economic cost to restricting CFCs, but the sacrifice was necessary to save life on earth. The CFC industry was small enough that its opposition was easily crushed for the greater good. Also, the remedy was simple and easy to understand – give up the convenience of CFCs as an aerosol propellant or likely die as the ozone hole grows. For politicians this scenario was perfect. Big problem caused by a relatively weak industry delivering a convenience, not a necessity. World saved; nice work guys!

Wouldn't it be wonderful if this process could be repeated to address the existential threats associated with manmade climate change? Forward thinking and compassionate politicians, scientists and business leaders join together and slay the dragon just in time. Let the celebration begin.

Except the climate issue is more complicated than CFCs. The remedies are many, but are often opposed by interest groups, principally the fossil fuel industry, which is both powerful and well-organized world-wide. The fossil fuel lobby

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stokes fear of economic decline resulting from restricting consumption of their products. They are actually helped in their opposition to climate change solutions by some environmentalists and political leaders who embrace sacrifice as a key part of addressing the climate challenge; after all, sacrifice of the convenience of CFC aerosol propellant was part of our salvation from the life threatening ozone hole. Steve Chapman of *The Chicago Tribune* makes the point that environmentalists and fossil fuelers' arguments converge on the issue of sacrifice.

This notion of sacrifice is a problem. Selling sacrifice to a weary public is difficult.

President Obama said to the UN, "no one gets a pass." This makes addressing climate change seem a shared heavy burden rather than an opportunity to build strength into the economy Most strategies to lessen the buildup of CO_2 would improve economic output. Yet, conservative political interests perceive liberals as using man-made climate change as a trump card to advance their liberal agenda. So conservatives react against climate change solutions. They hear former Vice President Al Gore saying "do as I say or the Earth gets it", and their very negative reaction to the messenger extends to the message as well. The Right fails to see that addressing climate change can actually increase wealth and quality of life.

For the most part reducing CO_2 means increasing energy efficiency; i.e. reducing energy/unit of output. Political conservatives appreciate and promote labor productivity; reduced labor/unit of output. Labor productivity is a basic ingredient of successful market economies, but then so is energy productivity. Engineering and invention have improved both labor and energy efficiency. When coal replaced wood, energy productivity increased. Oil has partially replaced coal with an accompanying increase in energy productivity. In the same way coal and oil producers are beginning to be pushed aside by market forces in the early 21st century, as solar, wind and other alternative fuels drop in price and people choose to live in more compact urban configurations. Insulation, more efficient windows and other conservation measures combined with emerging consumer preferences for walking, biking and transit have slowed and in some cases reversed energy consumption trends.

Market forces are driving energy efficiency. The public sector can help, but remember that governments looking to lead us away from calamity may get diverted by narrowly focused interests. For example, note the corn industry's shameless promotion of ethanol despite its dubious value or U.S. solar manufacturers' demand for tariffs and quotas on inexpensive solar panels from China, thus attempting to force their higher priced products on US customers. And of course the fossil fuel lobby will continue coercing governments to force their polluting products into the market place. They spend hundreds of $millions to pound in their messages implying that energy productivity threatens the economy. We need to counter this with the good news that energy productivity can improve economic and environmental outcomes.

Many government policies have inadvertently undermined energy efficiency. Federal housing programs such as the Federal Housing Administration's mortgage guarantees and low interest loan programs discriminate against mixed-use Main Street type development. As a result developers find it difficult to finance walkable projects that include retail and other commercial development. Recent relaxation of some of these policies is a sign that Federal administrators are aware of the problem, but programs like Fannie Mae and Freddie Mac still punish residential development that is attached to, for example, a coffee shop.

U.S. Department of Transportation (DOT) and the various state DOTs still build their policies around the goal of reducing congestion. While congestion can be a problem, it is also a sign of success in the urban context. All major successful cities, places like San Francisco, New York City, and Boston are congested with people who want to be there. Obsessive efforts to reduce congestion can actually damage cities as demonstrated in St. Louis and Detroit where heavy funding of wide, expensive highways rather than networks of more modest streets and avenues has helped generate economic decline. In Canada there is neither a national highway nor transit program and somehow Canadian cities have fairly good transit and surprisingly, with no equivalent to the U.S. Interstate program, highways connect the various provinces. What Canada does not have much of are big roads crashing through urban neighborhoods. Instead municipal government takes the lead and builds street networks and transit systems that add value to property and serve their residents and businesses. Transportation is a category of infrastructure where perhaps if the Federal government reduced its involvement, the U.S. would experience better economic and environmental outcomes.

We need to realize that the threat of climate change is different than the CFC/Ozone Hole threat. The solution is not only regulatory. It is probably too late to stop some severe climate effects so the CFC model of miraculous world cooperation saving us from climate change just in the nick of time is unrealistic. Cuts in CO_2 and other emissions are needed not just as a way to slow warming but as a catalyst to increase efficiency and quality of life. The positive benefits of reducing energy consumption need to be emphasized rather than just the apocalyptic dangers.